EVALUATION OF DIAPHRAGM ULTRASONOGRAPHY IN PREDICTING WEANING OUTCOMES FROM MECHANICAL VENTILATION

A THESIS SUBMITTED TO

BABA FARID UNIVERSITY OF HEALTH SCIENCES, FARIDKOT (PUNJAB)

IN THE PARTIAL FULFILLMENT

FOR THE AWARD OF DEGREE OF

DOCTORATE OF MEDICINE

IN

CRITICAL CARE MEDICINE

2023

Submitted By

DR APOORVA GUPTA

DEPARTMENT OF CRITICAL CARE MEDICINE
DAYANAND MEDICAL COLLEGE AND HOSPITAL
LUDHIANA, PUNJAB

DECLARATION BY THE CANDIDATE

I hereby declare that the thesis entitled "**EVALUATION OF DIAPHRAGM ULTRASONOGRAPHY IN PREDICTING WEANING OUTCOMES FROM MECHANICAL VENTILATION**" submitted towards partial fulfillment of the requirements for the award of **DOCTORATE OF MEDICINE IN CRITICAL CARE MEDICINE** degree to BFUHS is a compilation of original work carried out by me under the supervision of **Dr. Gunchan Paul**, Associate Professor, Department of Critical Care Medicine, **Dr. Parshotam Lal Gautam**, Professor & Head, Department of Critical Care Medicine. No part of this thesis has formed the basis for the award of any degree previously.

_____

Dr. APOORVA GUPTA
Department of
Critical Care Medicine,
Dayanand Medical College & Hospital,
Ludhiana, Punjab

Date:

Place:

CERTIFICATE OF SUPERVISORS

This is to certify that the work incorporated in this thesis entitled "**EVALUATION OF DIAPHRAGM ULTRASONOGRAPHY IN PREDICTING WEANING OUTCOMES FROM MECHANICAL VENTILATION"** has been carried out by **Dr. Apoorva Gupta** under our direct supervision. The data incorporated in this thesis is original and genuine and has been carried out by the candidate herself.

Signature of Supervisor

Dr. Gunchan Paul
Associate Professor
Department of Critical Care Medicine
DMC&H, Ludhiana

Signature of Co-Supervisor

Dr. Parshotam Lal Gautam
Professor & Head
Department of Critical Care Medicine
DMC&H, Ludhiana

Date:

ENDORSEMENT BY THE HEAD OF THE INSTITUTE

This is to certify that the thesis entitled "**EVALUATION OF DIAPHRAGM ULTRASONOGRAPHY IN PREDICTING WEANING OUTCOMES FROM MECHANICAL VENTILATION "** is a bonafide research work done by **Dr. Apoorva Gupta** under the supervision of **Dr. Gunchan Paul**, Associate Professor, Department of Critical Care Medicine, **Dr. Parshotam Lal Gautam**, Professor & Head, Department of Critical Care Medicine.

Principal

Dr. Sandeep Puri
Principal
DMC&H, Ludhiana

Date:

COPYRIGHT

Declaration by the Candidate

I hereby declare that the Baba Farid University of Health Sciences, Faridkot, shall have the rights to preserve & use this thesis in print or electronic format for academic/study purpose by the research scholar/students.

Signature

Dr. APOORVA GUPTA
Department of Critical Care Medicine,
Dayanand Medical College & Hospital,
Ludhiana, Punjab

Date:

© Baba Farid University of Health Sciences, Faridkot

Dedicated

to

my Family,

friends

&

Teachers

ACKNOWLEDGEMENT

To put emotions on paper is an incredibly difficult task. Words perhaps would fail to express my deep sense of gratitude and indebtedness to my guide and esteemed teacher, **Dr. Gunchan Paul**, Associate Professor, Department Of Critical Care Medicine, Dayanand Medical College and Hospital, Ludhiana for her encouragement and continuous support in carrying out this whole study at each and every step.

I am extremely thankful to my esteemed teacher and co-guide, **Dr. PL Gautam**, Professor & Head, Department of Critical Care Medicine, Dayanand Medical College and Hospital, Ludhiana for his continuous support, guidance and encouragement in carrying out this piece of work.

I am also indebted to all the patients who have contributed to this research-work through their consent and co-operation.

However, I shall not be able to put into words my appreciation for my husband, **Dr. Vikalp Khatri**, as without his moral support it would not be possible for me to complete this thesis. I am also grateful to my parents and parents-in-law for their constant support.

Finally, above all, I express my gratitude to the **Almighty God** for staying beside me in each and every step of my life.

DR APOORVA GUPTA

ABBREVIATIONS

A/C	Assist Control
AUC	Area Under the Curve
BMI	Body Mass Index
CAM ICU	Confusion Assessment Method for the Intensive Care Unit
CKD	Chronic Kidney Disease
CLD	Chronic Liver Disease
COPD	Chronic Obstructive Pulmonary Disease
COVID -19	Coronavirus Disease of 2019
D_0	Diaphragmatic excursion at zero minutes
D_{30}	Diaphragmatic Excursion at 30 minutes
D_5	Diaphragmatic Excursion at 5 minutes
DD	Diaphragmatic Dysfunction
DE	Diaphragmatic Excursion
DETI	Diaphragmatic Excursion Time Index
DOR	Diagnostic Odds Ratio
DTF	Diaphragmatic Thickness Fraction
DUS	Diaphragmatic Ultrasound
E-T	Excursion-Time
FiO2	fraction of inspired oxygen
GCS	Glasgow Coma Scale
HTN	Hypertension
ICU	Intensive Care Unit
IMV	Invasive Mechanical Ventilation
IQR	Interquartile Range
LVEDP	Left Ventricular End Diastolic Pressure
LVEF	Left Ventricular Ejection Fraction
MHz	Megahertz
MRC	Medical Research Council
MV	Mechanical Ventilation
NIF	Negative Inspiratory Force
NLR	Negative Likelihood Ratio
NPV	Negative Predictive Value
P0.1	Occlusion pressure at 100ms
paO2	partial pressure of Oxygen
PCV	Peak Contraction Velocity
Pdi	Pdi Transdiaphragmatic pressure
PEEP	Positive End Expiratory Pressure

pH	Potential of Hydrogen
PLR	Positive Likelihood Ratio
PPV	Positive Predictive Value
PRV	Peak Relaxation Velocity
PS	Pressure Support
PS/CPAP	Pressure Support/ Continuous Positive Airway Pressure
QUADAS-2	Quality Assessment of Diagnostic Accuracy Studies
ROC	Receiver Operating Characteristic
RR	Respiratory Rate
RSBI	Rapid Shallow Breathing Index
RV	Residual Volume
SBT	Spontaneous Breathing Trial
SOFA	Sequential Organ Failure Assessment Score
SPSS	Statistical Package for the Social Sciences
SROC	Summary Receiver Operator Characteristic
TDI	Tissue Doppler Imaging
TE	Thickness at end expiration
Ti	Inspiratory time
TI	Thickness at end inspiration
TLC	Total Lung Capacity
US	Ultrasound
USA	United States Of America
VALI	Ventilator Associated Lung Injury
VAP	Ventilator Associated Pneumonia
VTI	Velocity Time Integral

ABSTRACT

BACKGROUND AND OBJECTIVE: Diaphragm dysfunction is frequently involved in weaning failure hence, evaluation of diaphragmatic function at the time of weaning may have a promising role in the prediction of weaning outcomes. The objective of this study was to assess the role of diaphragm ultrasound parameters, Diaphragm excursion (DE), Diaphragm thickness fraction (DTF), Diaphragm excursion-time index (DETI) and Tissue Doppler Imaging (TDI) to predict weaning outcomes and to find out cut-off values of diaphragm TDI parameters.

MATERIALS AND METHODS: We conducted an institutional and prospective study in a tertiary care hospital for a duration of 12 months from January 2022 to December 2022. We enrolled 100 patients who had been on invasive mechanical ventilation for more than 24 hours and were weaning-ready on low levels of PS on PS/CPAP mode. We recorded lung mechanics and performed diaphragm ultrasound on them which was repeated after 30 minutes and 24 hours. All patients were followed up for 48 hours and were divided into 2 groups based on weaning success and failure. 76 patients succeeded while 24 patients failed the weaning trial.

RESULTS: Diaphragm excursion (ROC-AUC 0.903) excursion time index (ROC-AUC 0.864), thickness- fraction (ROC-AUC 0.869) and TDI parameters PCV (ROC-AUC 0.802) and PRV (ROC-AUC 0.781) can strongly predict weaning outcomes and even better than NIF (ROC -AUC 0.761), P0.1 (ROC-AUC 0.544) and RSBI (ROC-AUC 0.629). We found a statistically significant negative correlation between PCV vs DETI (r_s=-0.243, p=0.015) and PCV vs DE (r_s=-0.218,p=0.029), although not very strong.

CONCLUSION: The novel diaphragm ultrasound parameters like DETI and TDI of diaphragm are also good predictors of weaning outcomes along with diaphragm excursion and thickness fraction.

KEYWORDS: Diaphragm, DTF, DE, DETI, TDI, PCV, PRV, NIF, P0.1, RSBI

TABLE OF CONTENTS

S. NO.	TOPIC	PAGES
I	INTRODUCTION	1-3
II	AIMS AND OBJECTIVES	4
III	REVIEW OF LITERATURE	5-22
IV	MATERIALS AND METHODS	23-27
V	OBSERVATIONS AND RESULTS	28-68
VI	DISCUSSION	69-76
VII	SUMMARY AND CONCLUSIONS	77-78
VIII	BIBLIOGRAPHY	79-84

APPENDICES – I

- PROFORMA
- MASTER CHART

APPENDICES – II

- APPROVAL LETTER OF THESIS PLAN
- THESIS PLAN

LIST OF TABLES

Table No.	Title	Page No.
1.	AGE DISTRIBUTION OF TOTAL PATIENTS	29
2.	GENDER DISTRIBUTION OF TOTAL PATIENTS	30
3.	BMI DISTRIBUTION OF TOTAL PATIENTS	31
4.	DISTRIBUTION OF CO MORBIDITIES AMONGST ALL PATIENTS	32
5.	DISTRIBUTION OF SOFA (SEQUENTIAL ORGAN FAILURE ASSESSMENT) SCORES AMONGST ALL PATIENTS	33
6.	DISTRIBUTION OF GCS (GLASGOW COMA SCALE) AMONGST ALL PATIENTS	34
7.	DISTRIBUTION OF DELIRIUM AMONGST ALL PATIENTS	35
8.	WEANING OUTCOMES AMONGST ALL PATIENTS	36
9.	AGE GROUPS DISTRIBUTION AMONGST SUCCESS AND FAILURE GROUPS	37
10.	AGE STRATIFICATION (AGE < or > 50 YEARS) AND DISTRIBUTION AMONGST SUCCESS AND FAILURE GROUPS	39
11.	GENDER DISTRIBUTION AMONGST SUCCESS AND FAILURE GROUPS	40
12.	BMI DISTRIBUTION AMONGST WEANING SUCCESS AND FAILURE GROUPS	41
13.	DISTRIBUTION OF CO-MORBIDITIES AMONGST WEANING SUCCESS AND FAILURE GROUPS	43
14.	DISTRIBUTION OF DELIRIUM AMONGST WEANING SUCCESS AND FAILURE GROUPS	45
15.	COMPARISON OF ALL BASELINE CHARACTERISTICS BETWEEN THE 2 GROUPS.	46
16.	MULTIVARIATE REGRESSION ANALYSIS OF ALL BASELINE CHARACTERISTICS BETWEEN THE 2 GROUPS	48
17.	COMPARISON OF THE DIFFERENT DIAPHRAGM USG PARAMETERS ON PRESSURE SUPPORT MODE OF MECHANICAL VENTILATION	49
18.	COMPARISON OF THE DIFFERENT DIAPHRAGM USG PARAMETERS AFTER 30 MINUTES OF A T PIECE TRIAL	52
19.	COMPARISON OF THE DIFFERENT DIAPHRAGM USG PARAMETERS AFTER 24 HRS OF WEANING TRIAL	54

20.	AREA UNDER THE CURVE FOR ROCs OF DE, Ti, DETI, DTF ON PS/CPAP MODE OF MV	57
21.	DISTRIBUTION OF TDI PARAMETERS: PCV, PRV, VTI BETWEEN WEANING SUCCESS AND FAILURE GROUPS ON PS/CPAP- MV (PRESSURE SUPPORT MODE OF MECHANICAL VENTILATION)	58
22.	AREA UNDER THE CURVE (AUC) FOR ROC CURVES OF TDI PARAMETERS: PCV, PRV, VTI FOR PREDICTION OF WEANING OUTCOMES	62
23.	CORRELATION BETWEEN PCV-DE AND PCV-DETI	63
24.	AREA UNDER THE CURVE FOR NIF FOR WEANING FAILURE PREDICTION	66
25.	AREA UNDER THE CURVE FOR P0.1 FOR WEANING FAILURE PREDICTION	67
26.	AREA UNDER THE CURVE FOR RSBI FOR WEANING FAILURE PREDICTION	68

LIST OF FIGURES

Fig. No.	Title	Page No.
1.	STUDY PROFILE	28
2.	AGE DISTRIBUTION OF TOTAL PATIENTS	29
3.	GENDER DISTRIBUTION OF TOTAL PATIENTS	30
4.	BMI DISTRIBUTION OF TOTAL PATIENTS	31
5.	DISTRIBUTION OF CO MORBIDITIES AMONGST ALL PATIENTS	32
6.	DISTRIBUTION OF SOFA (SEQUENTIAL ORGAN FAILURE ASSESSMENT) SCORES AMONGST ALL PATIENTS	33
7.	DISTRIBUTION OF GCS (GLASGOW COMA SCALE) AMONGST ALL PATIENTS	34
8.	DISTRIBUTION OF DELIRIUM AMONGST ALL PATIENTS	35
9.	WEANING OUTCOMES AMONGST ALL PATIENTS	36
10.	AGE GROUPS DISTRIBUTION AMONGST SUCCESS AND FAILURE GROUPS	38
11.	AGE – DEPENDANT COMPARISON AMONGST SUCCESS AND FAILURE GROUPS STRATIFYING FOR PATIENT AGE < or > 50 YEARS	39
12.	GENDER DISTRIBUTION AMONGST SUCCESS AND FAILURE GROUPS	40
13.	BMI DISTRIBUTION AMONGST WEANING SUCCESS AND FAILUREGROUPS	42
14.	DISTRIBUTION OF CO-MORBIDITIES AMONGST WEANING SUCCESS AND FAILURE GROUPS	44
15.	COMPARISON OF THE DIFFERENT DIAPHRAGM USG PARAMETERS ON PRESSURE SUPPORT MODE OF MECHANICAL VENTILATION	50
16.	COMPARISON OF THE DIFFERENT DIAPHRAGM USG PARAMETERS AFTER 30 MINUTES OF A T PIECE TRIAL	53
17.	COMPARISON OF THE DIFFERENT DIAPHRAGM USG PARAMETERS AFTER 24 HRS OF WEANING TRIAL	55
18.	ROC CURVES FOR DE, Ti, DETI AND DTF ON PRESSURE SUPPORT MODE OF MECHANICAL VENTILATION FOR PREDICTION OF WEANING OUTCOMES	56
19.	DISTRIBUTION OF PCV BETWEEN WEANING SUCCESS AND FAILURE GROUPS ON PS/CPAP- MV (PRESSURE SUPPORT	59

	MODE OF MECHANICAL VENTILATION)	
20.	DISTRIBUTION OF PRV BETWEEN WEANING SUCCESS AND FAILURE GROUPS ON PS/CPAP- MV (PRESSURE SUPPORT MODE OF MECHANICAL VENTILATION)	59
21.	DISTRIBUTION OF VTI BETWEEN WEANING SUCCESS AND FAILURE GROUPS ON PS/CPAP-MV (PRESSURE SUPPORT MODE OF MECHANICAL VENTILATION)	60
22.	ROC CURVES OF TDI PARAMETERS: PCV, PRV, VTI FOR PREDICTION OF WEANING OUTCOMES.	61
23.	CORRELATION BETWEEN PCV AND DE ON PRESSURE-SUPPORT MODE OF VENTILATION	64
24.	CORRELATION BETWEEN PCV AND DETI ON PRESSURE-SUPPORT MODE OF VENTILATION	64
25.	ROC CURVE FOR NIF FOR WEANING FAILURE PREDICTION	66
26.	ROC CURVE FOR P0.1 FOR WEANING FAILURE PREDICTION	67
27.	ROC CURVE FOR RSBI FOR WEANING FAILURE PREDICTION	68

INTRODUCTION

Determination of the correct timing for extubation in patients receiving mechanical ventilation (MV) is very crucial as premature or delayed extubation may lead to variety of life-threatening complications. Predictors of the success of weaning and extubation are a topic of debate even among specialists as re-intubation is associated with an increase in hospital mortality. However, weaning failure and re-intubation rates of 10 to 15% are typical for most well-run ICUs as a target of zero percent is unrealistic and may lead to prolonged ventilation.[1] The physician's subjective ability to predict successful weaning has low accuracy; therefore, objective clinical manifestations and conditions have a significant role in prediction of weaning failure. [2] Many indices have been evaluated for this. Although traditional objective indices and rapid shallow breathing index (RSBI) may present a summary of the patient's overall conditions, they may not clarify the underlying reason for weaning failure.

The majority of patients are safely weaned from the ventilator after a first attempt; some are even extubated without any SBT. Thereby, weaning failure occurs in a minority of patients but represents an important burden in terms of days of mechanical ventilation, lengths of stay in intensive care unit (ICU) and morbidty-mortality. Investigating the causes of weaning failure is crucial because the duration of mechanical ventilation for those who fail the SBT or need re-intubation have both been associated with poor outcomes. Ultimately, identifying the reason why a patient fails the weaning process might help to reduce the duration of mechanical ventilation and hence to improve patient outcomes.

Difficult weaning is a real ICU challenge encountered in 20% to 30% of patients admitted to the ICU with invasive mechanical ventilation. [3] Weaning failure is defined as the failure to pass a spontaneous-breathing trial or the need for reintubation within 48 hours following extubation.[4] Among the many risk factors for delayed weaning, common ones include infections such as VAP (ventilator-associated

pneumonia) ventilator-associated lung injury (VALI), need for sedation and associated complications, airway trauma from prolonged intubation, deconditioning of respiratory muscles and psychological factors.[5]

Recent findings also suggest that diaphragm dysfunction is frequently involved in weaning failure and is associated with poor prognosis at time of liberation from mechanical ventilation. [6] Hence, evaluation of diaphragmatic function at the time of weaning may have a promising role in the prediction of successful weaning. But until recently, it was thought that accurate evaluation of the diaphragm was neither convenient nor achievable at the bedside. However, the growing interest in ultrasound seems to make this possible. Since diaphragmatic dysfunction accounts for a large number of extubation failures, evaluation of the diaphragm muscle with ultrasonography has recently been studied by many authors.[7] These studies not only show that ultrasonography can accurately diagnose diaphragm atrophy and paralysis but have also confirmed correlation of the ultrasonographically measured diaphragm muscle thickness with lung volumes during inspiration. In recent years, ultrasonography has been used extensively to evaluate diaphragmatic motion characteristics that have shown to carry prognostic implications in the outcome of weaning.[8] The principal diaphragm evaluations via ultrasonography (US) are the measurement of the diaphragmatic excursion (DE) and diaphragm muscle thickness during different phases of respiration. According to the literature, ultrasonographic assessment of diaphragm function has high and acceptable diagnostic accuracy when compared to the reference method of diaphragm assessment by phrenic nerve stimulation.[4] Also, it has the advantage of being a non-invasive technique especially in evaluation of critically ill patients admitted to intensive care units (ICUs). Although recent studies have contributed to promoting our knowledge of use and advantages of ultrasound in evaluation of function of the diaphragm, it has not been considered as a conventional approach to predict the optimal extubation time. Thus,

there remains a need for a more reliable, accurate and applicable diaphragmatic index for prediction of the weaning outcome.

As diaphragm is the muscle of fundamental importance for successful spontaneous ventilation, when external elastic load is added in an incremental fashion during weaning, there is a progressive reduction in tidal volume with increasing rate causing a rapid shallow breathing pattern. The breathing pattern and adaptation of the diaphragm to increased mechanical loads during spontaneous breathing trials (SBTs) using the Diaphragmatic excursion time index (DETI) may be pivotal in determining the outcome of extubation. [9]

Doppler ultrasound detects the frequency shift of ultrasound signals reflected by moving objects. Tissue Doppler Imaging (TDI) is an echocardiographic technique that uses the same Doppler principles to measure the high-amplitude, low-velocity signal of cardiac tissue motion. TDI measurements are robust, easy to obtain, and offer valuable information in various cardiac pathologies. So far, TDI of diaphragmatic tissue motion has been studied very little in adults. [10]

Hence, we aim to assess the role of diaphragm ultrasound parameters namely, Diaphragm excursion, Diaphragm thickness fraction (DTF), Diaphragm excursion-time index (DETI) and Tissue Doppler Imaging (TDI) during weaning from invasive mechanical ventilation and compare the ultrasonongraphic diaphragmatic values with lung mechanics and traditional weaning criteria.

AIMS AND OBJECTIVES

Primary objective:

1. To assess the role of diaphragm ultrasound parameters, Diaphragm excursion (DE), Diaphragm thickness fraction(DTF), Diaphragm excursion-time index (DETI) and Tissue Doppler Imaging (TDI) during weaning success and failure from invasive mechanical ventilation.
2. To find out cut off TDI values: PCV (peak contraction velocity), peak relaxation velocity (PRV) and VTI (velocity time integral) of diaphragmatic muscle motion for predicting weaning outcomes.

Secondary objective:

1. To compare the ultrasononographic diaphragmatic values (diaphragmatic excursion, thickness fraction, diaphragm excursion-time index and TDI) with lung mechanics and traditional weaning criteria.

REVIEW OF LITERATURE

Up to 25% of critically ill patients experience difficulties in weaning from invasive mechanical ventilation (IMV), burdening the intensive care unit (ICU) with long lengths-of-stay, prolonged mechanical ventilation (MV), and increased morbidity and mortality. Weaning failure is commonly described as a failed spontaneous breathing trial (SBT) or the reinstitution of mechanical ventilation within 48 hours after extubation. [6] Failed extubation complicates up to 30% of successful spontaneous breathing trials and correlates with higher morbidity and mortality rates. [11]

Determining the optimal time to extubate a patient continues to be a challenge. Prolonged mechanical ventilation is associated with a series of adverse effects (e.g., tracheal lesions, ventilator-associated pneumonia, ventilator-induced lung injury, and ventilator-induced diaphragm injury) [12], whereas premature extubation exposes the patient to cardiovascular stress due to spontaneous breathing, often requiring the reinstitution of ventilatory support.[13] Although international guidelines recommend the implementation of spontaneous breathing trials , used alone this practice is ineffective in predicting weaning failure and reintubation. [14, 15] A number of studies have investigated and proposed different parameters as outcome predictors of weaning from mechanical ventilation; however, a clear understanding of the ideal time to proceed with extubation for a successful outcome continues to elude us.[16] Cardiac failure, diaphragmatic dysfunction and acute respiratory illness (lung parenchymal disease, or upper or lower airway obstructions), neurological status, and intra-abdominal issues are among the known leading causes of failed weaning. [17]

A comprehensive approach to invasive mechanical ventilation should include an extensive ultrasonographic assessment of cardiac function, diaphragmatic activity, and lung parenchyma. In particular, much light has been shone on the use of ultrasonographic assessment of diaphragmatic dysfunction as a predictor of weaning failure. Still, the

diaphragm does not receive excessive attention at the expense of other predictive factors. A simultaneous and comprehensive ultrasound examination of the cardio- pulmonary-diaphragmatic district may confer valuable predictive information regarding successful weaning from mechanical ventilation, although literature in this regard is still limited. [18] It is also important to bear in mind that other factors able to negatively influence the weaning outcome exist outside the cardio-pulmonary- diaphragmatic area (i.e., the neurological status and intra-abdominal hypertension) that cannot be evaluated with ultrasound. Mechanical ventilation can negatively affect the factors involved in respiratory function; for example, ventilator- induced lung injury, impaired cardiac performance, and ventilator-induced diaphragmatic dysfunction are all possible consequences.

The weaning process

Weaning from mechanical ventilation starts with the institution of mechanical ventilation; from the outset, the physician assesses the patient on a daily basis to determine when they might be ready to wean. Invasive mechanical ventilation (IMV) is a risky journey for a critically ill patient admitted to the intensive care unit because of acute illness, IMV itself, or a failed weaning attempt. Weaning is the process in which the breathing effort is progressively returned from the machine to the patient. This process consists of 3 key steps,:

1. When the patient's clinical conditions permit it, ventilation supports are progressively decreased (*Ready, weaning*!)
2. A spontaneous breathing trial (SBT) assesses the patient's capability to breathe autonomously (*Ready, breathing*!)
3. The patient is liberated from mechanical ventilation (*Ready, extubation!*). [19] Three main SBT strategies are described in the literature: the T-piece trial; the continuous positive airway pres-sure (CPAP) trial—in which the CPAP applied is equal to the previously applied positive end-expiratory pressure (PEEP); and pressure

support ventilation, which uses a low level of pressure support (5–8 cmH_2O).

No standardized SBT method has been identified to date in terms of type or duration (30–120 min) that can ensure a higher rate of successful weaning. However, strong evidence does exist supporting the employment of a short-term (30 min) breathing trail and low-level pressure support (8 cmH_2O). [20] If the SBT is accompanied by patient discomfort (i.e., anxiety or fatigue) and/or cardio-respiratory distress (i.e., RR≥35 bpm, SpO_2 < 90%, HR variability > 20%, hemodynamic instability), then it is considered to have failed. In the absence of such responses, the SBT is deemed successful and the patient can be considered for airway removal. Although heterogeneity exists in the definition of successful weaning, it is generally taken as the patient's capacity to maintain spontaneous breathing for at least 48 h following extubation. As mentioned above, despite international guidelines recommending the implementation of spontaneous breathing trials , used alone SBTs are ineffective in predicting weaning failure and reintubation . One possible solution to this may be the implementation of integrated cardio- pulmonary-diaphragmatic assessments for the detection of predictive indicators of weaning failure. [18]

Weaning from mechanical ventilation

Regarding fluid management procedures in shock patients, recent literature has schematized its practice into four different phases, adopting the acronym ROSE: resuscitation (R), optimization (O), stabilization (S), and evacuation (E). [21] Resuscitation, in some cases, could be too aggressive with the risk of fluid-overload, whereas evacuation could be too fast with the risk of hypovolemia and low cardiac output state. In the first case, previous over-hydration with a positive fluid balance has been associated with death and an increased risk of failed weaning from mechanical ventilation in surviving patients. [22] This could be explained by the fact that shifting the patient from mechanical ventilation (positive airway pressure) to a T-piece trial (negative airway pressure) can increase cardiac preload and unmask

an underlying cardiac problem. Lemaire and colleagues were the first to demonstrate this vicious circle.[13] Potential cardiac complications can be monitored in 3 main ways: one is direct but invasive— measurement of the cardiac filing pressure by pulmonary arterial catheter (PAC); the remaining two are indirect and non-invasive— one entails the use of heart or lung ultrasound, and the other the rapid measurement of natriuretic peptide for the diagnosis of acute heart failure.[18]

Monitoring for cardiac complications is necessary because the sensitivity and specificity of clinical signs of acute heart failure in intensive care patients are poor. PAC is reserved for specific severe cases. It is used for the diagnosis and treatment of pulmonary arterial hypertension and to guide fluid and catecholamine management; however, its routine use has been abandoned globally due to the lack of any outcome benefits.[23] Ultrasound, on the other hand, has become an invaluable tool in the ICU thanks to its widespread availability at the patient's bedside and the absence of any known side effects. [18] Moreover, the role of echocardiography in the detection of cardiac origins of weaning failure has grown significantly over the last 15 years. In particular, we now know that impaired systolic function (i.e., a small left ventricular ejection fraction [LVEF]) is less frequently associated with weaning failure in patients who failed the SBT (33% of cases) than left ventricular diastolic dysfunction (67% of cases). [18,24] To investigate this latter condition, trans-mitral flow is interrogated using a pulse wave Doppler placed over the mitral valve in an apical four-chamber view. An early wave (E wave) is displayed on the monitor, that represents the first phase of the diastole as a passive phenomenon, limited only by the stiffness of the left ventricle or by interventricular inter-dependence—right ventricular push over the left ventricle via the septum. A stiff ventricle generates an elevated filling pressure, leading to pulmonary edema. In addition to trans-mitral Doppler, an E wave in patient with sinus rhythm is followed by atrial contraction (A wave). The left ventricular preload is the sum of the E and A waves at a price of low or average left ventricular end-diastolic pressure (LVEDP) less

than 12–14 mmHg. However, to estimate the LVEDP non-invasively, the E/A ratio has shown to be preload dependent and insufficient.[18] On the other hand, tissue Doppler directly measures myocardial velocities by means of the E' wave in a load-independent way. The combination of the trans-mitral Doppler E wave, the tissue Doppler E' wave, and the *E*/*E*' ratio at the end of an SBT also seems to be capable of predicting weaning failure from diastolic dys-function in patients with arrhythmia, immediately after and 10 min after extubation, with an area under the curve (AUC) of 0.75 and 0.86, respectively. However, two main limitations of these methods need to be recognized. First, although an *E*/*E*' value<8 can accurately identify patients with a normal LVEDP, and an *E*/*E*' value > 15 can identify those with an elevated LVEDP, a gray zone exists between the values of 8 and 15 ; second, not all intensive care clinicians possess advanced echocardiography skills; and third, LVEDP may also be elevated in cases of increased intra-abdominal pressure.[18]

In a very recent study, by Ferré A et al lung ultrasound evaluating the delta-B-lines before and after SBT in the four anterior chest wall regions was shown to provide excellent correlation with successful weaning.[25] However, the shift from mechanical to spontaneous ventilation may alone justify the appearance of such artifacts. Furthermore, distinguishing between cardiogenic and inflammatory causes of delta-B-lines may be a challenge.

Lastly, natriuretic peptides, and in particular brain natriuretic peptide (BNP), have been studied for their potential to predict weaning failure. In their study, Mekontso-Dessap et al. reported the outcome of two weaning strategies, one of which was driven by BNP level, whereas the other followed no explicit protocol. [26] They found that the BNP-guided fluid strategy was associated with increased use of diuretics, more negative fluid balance leading to a shorter mechanical ventilation time, and more ventilator-free days, but no change in ICU length-of-stay, morbidity, or mortality. The authors suggest that the changes in BNP that occur in the ICU are relatively slow and may be influenced by renal insufficiency or by the use of extracorporeal renal replacement therapy.

One-third of weaning failures with a cardiac origin depend on systolic dysfunction. [18] In the case of cardiogenic shock, the diaphragmatic blood flow decreases and diaphragm muscular function can become compromised. In normal conditions, the diaphragmatic blood flow significantly increases with a high level of muscle contraction. Indeed, the diaphragmatic blood flow is strictly dependent on cardiac output in both individuals at rest and with increased muscular activity. Thus, since the diaphragm requires a high blood flow—in fact it is the skeletal muscle receiving the largest volume of blood per gram of tissue—diaphragm function may be impaired by a reduction in blood flow. [27, 18]
In patients with cardiogenic shock, respiratory muscles, which are the only muscles working during low cardiac output, shift to anaerobic metabolism resulting in lactate production even though they may be receiving a large fraction of the cardiac output. As a consequence, skeletal muscles and vital organs receive less blood flow, contributing to an increased production and impaired removal of lactate. The onset of acidemia and hypoxemia then leads to an increase in the work of breathing due to induced compensatory hyperventilation. Of note, whenever the muscle oxygen and nutrient demands exceed the supply, the diaphragm's ability to generate and sustain force decreases and muscle failure ensues. [28] During cardiogenic shock, the imbalance between demand and supply is facilitated by the reduced cardiac output and diaphragmatic blood flow. [18]

Diaphragm ultrasound (DUS)

The diaphragm is a fundamental respiratory muscle whose dysfunction may be very common in patients undergoing mechanical ventilation. Diaphragm dysfunction is associated to prolonged mechanical ventilation and weaning failure. The diagnostic tools traditionally used to study diaphragm dysfunction, like fluoroscopy, phrenic nerve conduction study, and trans-diaphragmatic pressure measurement, present some limitations and disadvantages, including the use of ionizing radiation, low availability, invasiveness, and the need for patient transportation and skilled or specifically trained operators. Recently, ultrasound has been used to evaluate diaphragmatic

function. Advantages of ultrasound include safety, avoidance of radiation hazards, and availability at the bedside. [29]

WHY DIAPHRAGM FUNCTION MONITORING IS IMPORTANT IN THE ICU?

Diaphragm dysfunction is a common condition

A landmark study published by Levine et al. [30] demonstrated rapid disuse-induced atrophy of diaphragm fibers in brain-dead adult donors exposed to several hours of mechanical ventilation. This observation is consistent with a core of animal studies and more recent ultrasound-based analysis demonstrating the impact of ventilator-induced diaphragm disuse on diaphragm atrophy and dysfunction. [31] ICU patients are exposed to several other risk factors of diaphragm dysfunction in addition to mechanical ventilation-induced disuse (i.e., sepsis, critical illness severity) making it difficult to determine the specific contribution of mechanical ventilation to the development of diaphragm dysfunction. Regardless of the risk factors involved, various studies have reported a high prevalence of diaphragm dysfunction in the ICU, as more than two-thirds of mechanically ventilated patients are diagnosed with diaphragm dysfunction at the time of the first weaning attempt. [32]

WHAT IS DIAPHRAGM FUNCTION AND HOW CAN IT BE MONITORED IN THE ICU?

The diaphragm is a musculotendinous structure stretched between the thorax and the abdomen, making direct examination impossible. Bedside investigation of diaphragm function requires costly equipment and involves semi-invasive approaches. For these reasons, apart from research purposes, diaphragm function monitoring has rarely been performed in clinical practice in recent years. However, things have changed with the emergence of techniques such as diaphragm ultrasound and recording of the electrical activity of the diaphragm by means of a dedicated esophageal catheter.[31]

Pressure-generating capacity

The physiological function of the diaphragm is to shorten and produce a force. Although this force cannot be measured directly, the capacity of the diaphragm to generate a pressure can be measured. When the diaphragm contracts, it descends toward the abdomen, which simultaneously generates increased abdominal pressure and decreased thoracic pressure, resulting in a transdiaphragmatic pressure (P_{di}). The maximum P_{di}, which is the P_{di} generated by a forced inspiratory effort, is considered to be the most physiological approach to assessment of diaphragm function. However, ICU patients are generally unable to produce maximum effort because of lack of cooperation induced by sedation or delirium. To overcome this issue, it has been proposed to measure P_{di} in response to supramaximal bilateral magnetic phrenic nerve stimulation (P_{di}, twitch). Although P_{di} in response to magnetic stimulation is not a substitute for maximum P_{di}, it has the advantage of being independent of the patient's cooperation and is able to provide standardized measurements. As measuring transdiaphragmatic pressure requires both esophageal and gastric balloons, it is acceptable to exclusively use changes in tracheal pressure during magnetic phrenic nerve stimulation ($P_{tr,stim}$) to evaluate diaphragm function. A $P_{tr,stim}$ less than -11 cmH_2O is used to define diaphragm dysfunction in the ICU.

Diaphragm ultrasound

Recent literature suggests that diaphragm dysfunction (DD) is frequently involved during weaning failure and that it is associated with poor prognosis at the time of liberation from mechanical ventilation. Recently, ultrasonographic evaluation of the diaphragm muscle has shown promising improvement in the prediction of successful weaning, since DD accounts for a large number of extubation failures. [1] Studies not only have confirmed correlation of the ultrasonographically measured diaphragm muscle thickness with lung volumes during inspiration, but also accurately diagnosed diaphragm atrophy and paralysis. Two principal diaphragm evaluations via ultrasonography (US) are the measurement of the diaphragmatic excursion (DE) and

calculation of the diaphragm muscle thickness during inspiration and expiration. [1] According to the literature, these imaging techniques are non-invasive and seem to provide high and acceptable diagnostic accuracy in evaluation of the diaphragm function when compared to the reference method of diaphragm assessment which is phrenic nerve stimulation, especially in critically ill patients admitted to intensive care units (ICUs). [33]

Zhang X et al conducted a study to explore the value of the right hemi-diaphragmatic excursion (DE) and its variation in predicting extubation outcome in mechanically ventilated patients with COPD. All included patients with COPD received mechanical ventilation (MV) and were ready to wean from MV. After patients passed the 30 min spontaneous breathing trail (SBT), extubation was considered to be feasible, and the right DE measured by ultrasound at 0 min, 5 min, and 30 min of SBT were named as DE_0, DE_5, and DE_{30}, respectively. Twenty-five patients succeeded extubation; 12 patients failed. The area under receiver operator characteristic curve (AUC_{ROC}) of DE_{30} and ΔDE_{30-5} (the variation between 30 and 5 min) were 0.762 and 0.835; a cutoff value of $DE_{30} > 1.72$ cm and $\Delta DE_{30-5} > 0.16$ cm were associated with a successful extubation with a sensitivity of 76% and 84%, a specificity of 75% and 83.3%, respectively. The predictive probability equation of the DE_{30} plus ΔDE_{30-5} was $P = 1/ [1 + e^{-(-5.625+17.689\times\Delta DE_{30-5}+1.802\times DE_{30})}]$, a cutoff value of $P > 0.626$ was associated with a successful extubation with the AUC_{ROC} of 0.867, a sensitivity of 92%, and a specificity of 83.3%.They concluded that combination of DE_{30} and ΔDE_{30-5} could improve the predictive value and could be used as the predictor of extubation outcome in mechanically ventilated patients with COPD.[34]

Mahmoodpoor A et al, in their systematic review and meta-analysis evaluated and compared the accuracy of the diagnostic indices obtained by ultrasonographic examination, including diaphragm thickening fraction (DTF), diaphragmatic excursion (DE) and the rapid shallow breathing index (RSBI). A systematic literature search (Web of Science, MEDLINE, Embase and Google Scholar) was performed to identify original articles assessing diaphragm muscle features including

excursion and thickening fraction. A total of 2738 citations were retrieved initially; available data of 19 cohort studies (1114 patients overall) were included in the meta-analysis, subdivided into groups based on the ultrasonographic examination type. Their results showed the superiority of the diagnostic accuracy of the DTF in comparison to the DE and the RSBI. Data on the combination of the different indices were limited. They inferred that DTF in the assessment of weaning outcome provides more promising outcomes, which should be evaluated more meticulously in future randomised trials.[1]

Palkar A et al, in their study, used ultrasonography to evaluate the performance of the excursion-time (E-T) index—a product of diaphragm excursion and inspiratory time, to predict the outcome of extubation. Right hemidiaphragm excursion, inspiratory time, and E-T index were measured by ultrasonography during mechanical ventilation: (1) on assist-control (A/C) mode during consistent patient-triggered ventilation, (2) following 30 min during a spontaneous breathing trial (SBT), and (3) between 4 and 24 h following extubation. These measurements were correlated with the outcome of extubation. Patients in the “failure” group required reintubation or noninvasive ventilation within 48 h of extubation. Of the 73 patients studied, 20 patients failed extubation. During SBT, diaphragm excursion was 1.65 0.82 and 2.1 0.9 cm (P 1⁄4 .06), inspiratory time was 0.89 0.30 and 1.11 0.39 s (P 1⁄4 .03), and the E-T index was 1.64 1.19 and 2.42 1.55 cm-s (P < .03) in the “failure” and “success” groups, respectively. The mean change in E-T index between A/C and SBT was –3.9 57.8% in the failure group and 59.4 74.6% in the success group (P < .01). A decrease in diaphragmatic E-T index less than 3.8% between A/C and SBT had a sensitivity of 79.2% and a specificity of 75%, to predict successful extubation. They concluded, that diaphragm E-T index measured during SBT may help predict the outcome of extubation. Maintenance or increase in diaphragm E-T index between A/C and SBT increases the likelihood of successful extubation. [9]

Vetrugno L et al., in their study hypothesizes that ultrasound measured diaphragmatic thickening fraction (DTF) could provide corroborating information for weaning COVID-19 patients from mechanical ventilation. Their's was an observational, pragmatic, cross-sectionan, multicenter study in 6 Italian intensive care units. DTF was assessed in COVID-19 patients undergoing weaning from mechanical ventilation from 1st March 2020 to 30th June 2021. Primary aim was to evaluate whether DTF is a predictive factor for weaning failure.[35] Fifty-seven patients were enrolled, 25 patients failed spontaneous breathing trial (44%). Median length of invasive ventilation was 14 days (IQR 7–22). Median DTF within 24 h since the start of weaning was 28% (IQR 22–39%), RASS score (− 2 vs − 2; $p = 0.031$); Kelly-Matthay score (2 vs 1; $p = 0.002$); inspiratory oxygen fraction (0.45 vs 0.40; $p = 0.033$). PaO_2/FiO_2 ratio was lower (176 vs 241; $p = 0.032$) and length of intensive care stay was longer (27 vs 16.5 days; $p = 0.025$) in patients who failed weaning. The generalized linear regression model did not select any variables that could predict weaning failure. DTF was correlated with pH (RR 1.56×10^{27}; $p = 0.002$); Kelly-Matthay score (RR 353; $p < 0.001$); RASS (RR 2.11; $p = 0.003$); PaO_2/FiO_2 ratio (RR 1.03; $p = 0.05$); SAPS2 (RR 0.71; $p = 0.005$); hospital and ICU length of stay (RR 1.22 and 0.79, respectively; $p < 0.001$ and $p = 0.004$). They inferred that DTF in COVID-19 patients was not predictive of weaning failure from mechanical ventilation, and larger studies are needed to evaluate it in clinical practice further.[36]

Ferrari et al., 2014 in their study evaluated the weaning index consisting in the diaphragm thickening fraction (DTF) assessed by ultrasound. Forty-six patients were prospectively enrolled. All patients were ventilated in pressure support througha tracheostomy tube. Patients underwent a spontaneous breathing trial (SBT) when they met all the following criteria: $FiO_2 < 0.5$, PEEP ≤5 cmH_2O, $PaO_2/FiO_2 >$ 200, respiratory rate <30 breaths per minute, absence of fever,alert and cooperative, and hemodynamic stability without vasoactive therapy support. During the trial, the right hemidiaphragm was visualized in the

zone of apposition using a 10-MHz linear ultrasound probe. The patientwas then instructed to perform breathing to total lung capacity (TLC) and then exhaling to residual volume (RV). Diaphragm thickness was recorded at TLC and RV, and the DTF was calculated as percentage from the following formula: Thickness at end inspiration − Thickness at end expiration / Thickness at end expiration. Also, the rapid shallow breathing index (RSBI) was calculated. Weaning failure was defined as the inability to maintain spontaneous breathing for at least 48 h, without any form of ventilatory support. A significant difference between diaphragm thickness at TLC and RV was observed both in patients who succeeded SBT and patients who failed. DTF was significantly different between patients who failed and patients who succeeded SBT. A cutoff value of a DTF >36% was associated with a successful SBT with a sensitivity of 0.82, a specificity of 0.88, a positive predictive value (PPV) of 0.92, and a negative predictive value (NPV) of 0.75. By comparison, RSBI <105 had a sensitivity of 0.93, a specificity of 0.88, a PPV of 0.93, and a NPV of 0.88 for determining SBT success. This study showed that in their cohort of patients, the assessment of DTF by diaphragm ultrasound may perform similarly to other weaning indeces. They suggested that upon validation by other studies, this method may be used in clinical practice. [29]

Pirompanich and Romsaiyut, in their study have evaluated efficacy of a combination of DTF and RSBI for predicting successful weaning compared to RSBI alone. They enrolled patients from the medical intensive care unit or ward who were using mechanical ventilation and readied for weaning. Patients underwent a spontaneous breathing trial (SBT) for 1 h, and then, both hemi-diaphragms were visualized in the zone of apposition using a 10-MHz linear probe. Diaphragm thickness was recorded at the end of inspiration and expiration which supposed the lung volume equal to total lung capacity (TLC) and residual volume (RV), respectively, and the DTF was calculated as a percentage from this formula: thickness at TLC minus thickness at RV divided by thickness at RV. In addition, RSBI was calculated at 1 min after SBT. Weaning failure was defined as the inability to maintain spontaneous

breathing within 48 h. Of the 34 patients enrolled, the mean (± SD) age was 66.5 (± 13.5) years. There were 25 patients with weaning success, 9 patients in the weaning failure group. The receiver operating characteristic curves of right and left DTF and the RSBI for the prediction of successful weaning were 0.951, 0.700, and 0.709, respectively. The most accurate cut-off value for prediction of successful weaning was right DTF ≥ 26% (sensitivity of 96%, specificity of 68%, positive predictive value of 89%, negative predictive value of 86%). The combination of right DTF ≥ 26% and RSBI ≤ 105 increased specificity to 78% but slightly decreased sensitivity to 92%. Intra-observer correlation increased sharply to almost 0.9 in the first ten patients and slightly increased after that. They inferred that the combination of right DTF and RSBI greatly improved the accuracy for prediction of successful weaning compared to RSBI alone. [37]

Saravanan et al. conducted a prospective study to determine the use of diaphragm ultrasound in weaning ventilated patients. This study was done on 200 adult patients on mechanical ventilation for more than 24 h. After meeting the clinical weaning criteria, a spontaneous breathing trial (SBT) was performed. RSBI was recorded and a bedside ultrasound of the diaphragm was performed to measure diaphragmatic excursion (DE) and diaphragm thickening fraction (DTF) before extubation. They assessed the predictability of weaning success of RSBI, DE and DTF by determining the area under the receiver operating characteristic (AUROC) curve and Youden's index. The requirement of non-invasive ventilation or re-intubation within 48 h was considered a weaning failure. Out of the 200 patients studied, 171 were successfully weaned. The AUROC values for RSBI, DTF, DE, RSBI-DTF and RSBI-DE for successful weaning prediction were 0.422, 0.654, 0.809, 0.656 and 0.807, respectively. The predictability using cut-off values were DE >1.21 cm (sensitivity 94%, specificity 71%, Youden's index 0.65), DTF >37% (sensitivity 80%, specificity 52%, Youden's index 0.31) and RSBI <82 (sensitivity 94%, specificity 31%, Youden's index 0.25). Both DE and DTF showed a higher specificity

than RSBI and a combination of RSBI-DE and RSBI-DTF was found to be better than using RSBI alone. [38]

Li et al. performed a meta-analysis to assess the accuracy of diaphragmatic ultrasonography for predicting reintubation within 48 hours of extubation. Literature search was performed in PubMed, Embase, and Cochrane Library to identify all the relevant papers, published in English up to July 16, 2017. Eligible studies were included if data were in adequate details to rebuild 2×2 contingency tables. Methodological quality of the included studies was evaluated using the Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) in Review Manager 5.3. The sensitivity, specificity, positive likelihood ratio (PLR), negative likelihood ratio (NLR), diagnostic odds ratio (DOR), and summary receiver operating characteristic (SROC) curve were pooled using the fixed or random effects model, meanwhile, the heterogeneity was evaluated using Cochran *Q* test and I^2 statistics in Meta-DiSc 1.4. Publication bias was assessed using Deeks funnel plot in Stata 12.0. Thirteen studies with 742 subjects were included in this meta-analysis. The pooled sensitivities for diaphragm excursion (DE) and diaphragm thickness fraction (DTF) were 0.786 and 0.893, and the pooled specificities were 0.711 and 0.796, respectively. The area under curve (AUC) for DE and DTF were 0.8590 and 0.8381. The DORs for DE and DTF were 10.623 and 32.521. No publication bias was observed among these studies. They concluded that diaphragmatic ultrasonography is a promising tool for predicting reintubation within 48 hours of extubation. However, due to heterogeneities among the included studies, large-scale studies are warranted to confirm their findings. [39]

Gok et al., 2021 did a study to investigate predictive values of diaphragmatic thickening fraction (DTF), diaphragmatic excursion (DE), and anterolateral lung ultrasound (LUS) scores in extubation success and compare with rapid shallow breathing index (RSBI) in patients extubated under traditional parameters. Patients undergoing mechanical ventilation for >48 hours were included in the study. In patients planned for extubation, sonographic evaluations of the

diaphragm and lung were performed at the T-tube stage. RSBI was achieved in the pressure support (PS) ventilation stage. Predictive values of DTF, DE, and anterolateral LUS scores were compared with RSBI in extubation success. Sixty-two patients were enrolled in the study. The study population consisted mostly of trauma patients (77%). A cut-off value of 64 was obtained for RSBI. The positive predictive value (PPV) was found at 97% in extubation success. Cut-off values of 27.5 for DTF, 1.3 cm for the DE, and 6.5 for LUS scores were obtained at the T-tube stage, respectively. PPVs of all sonographic parameters were found over 90%. At the first stage, weaning and extubation failures were determined as 35 and 9.6%, respectively. RSBI was found as a powerful parameter in determining extubation success ($r=0.774$, $p\leq0.001$) and moderately correlated with sonographic parameters. They concluded from this study that investigating the lung and diaphragm via ultrasound provides real-time information to increase extubation success. Cut-off values of 64 for RSBI, 27.5 for DTF, 1.3 cm for the DE, and 6.5 for LUS scores were obtained, respectively, and PPVs of all sonographic parameters were found over 90%. They considered that sonographic evaluations accompanied by an RSBI will increase extubation success in the weaning process. [40]

DiNino et al., 2014 conducted a study to evaluate if ultrasound derived measures of diaphragm thickening, rather than diaphragm motion, can be used to predict extubation success or failure. Sixty-three mechanically ventilated patients were prospectively recruited. Diaphragm thickness (tdi) was measured in the zone of apposition of the diaphragm to the rib cage using a 7–10 MHz ultrasound transducer. The percent change in tdi between end-expiration and end-inspiration (Δtdi%) was calculated during either spontaneous breathing (SB) or pressure support (PS) weaning trials. A successful extubation was defined as SB (spontaneous breathing) for >48 h following endotracheal tube removal. Of the 63 subjects studied, 27 patients were weaned with SB and 36 were weaned with PS. The combined sensitivity and specificity of Δtdi%≥30% for extubation success was 88% and 71%, respectively. The positive predictive value and negative

predictive value were 91% and 63%, respectively. The area under the receiver operating characteristic curve was 0.79 for Δtdi%.They concluded that ultrasound measures of diaphragm thickening in the zone of apposition may be useful to predict extubation success or failure during SB or PS (Pressure Support) trials. [41]

TDI (Tissue Doppler Imaging) of diaphragmatic tissue motion has been studied so far very little in adults. It is an echocardiographic method that measures the velocity of moving tissue. [10]

Soilemezi et al. applied this technique to the diaphragm to assess the velocity of diaphragmatic muscle motion during contraction and relaxation. In 20 healthy volunteers, diaphragmatic TDI was performed to assess the pattern of diaphragmatic motion velocity, measure its normal values, and determine the intra- and interobserver variability of measurements. In 116 consecutive ICU patients, diaphragmatic excursion, thickening, and TDI parameters of peak contraction velocity, peak relaxation velocity, velocity–time integral, and TDI-derived maximal relaxation rate were assessed during weaning. In a subgroup of 18 patients, transdiaphragmatic pressure (Pdi)-derived parameters (peak Pdi, pressure–time product, and diaphragmatic maximal relaxation rate) were recorded simultaneously with TDI. In terms of reproducibility, the intercorrelation coefficients were >.0.89 for all TDI parameters exhibited lower values for all TDI parameters compared with weaning failure patients, except for velocity–time integral, as follows: peak contraction velocity, 1.35 +/- 0.34 versus 1.50 +/- 0.59 versus 2.66 +/- 2.14 cm/s ($P < 0.001$); peak relaxation velocity, 1.19 +/- 0.39 versus 1.53 +/- 0.73 versus 3.36 +/- 2.40 cm/s ($P < 0.001$); and TDI- maximal relaxation rate3.64 +/- 2.02 versus 10.25 +/- 5.88 versus 29.47+/-23.95cm/s^2 ($P<0.001$),respectively. Peak contraction velocity was strongly correlated with peak transdiaphragmatic pressure and pressure–time product, whereas Pdi-maximal relaxation rate was significantly correlated with TDI-maximal relaxation rate. They inferred from this study that diaphragmatic tissue doppler allows real-time assessment of the diaphragmatic tissue motion velocity. Diaphragmatic TDI-derived parameters differentiate patients who fail a weaning trial

from those who succeed and correlate well with Pdi-derived parameters. [10]

Tissue Doppler Imaging (TDI) is a newer ultrasound technique introduced more than two decades ago to evaluate cardiac function. Unlike the traditional Doppler technique, which assesses high-frequency low-amplitude blood velocities, TDI uses a low-pass filter to characterize low-velocity high-amplitude signals arising from myocardial tissue. For the heart, TDI mainly interrogates tissue velocities in the longitudinal direction, where the apex of the heart is considered immobile and the base of the heart moves toward the apex (transducer) in systole and away from the apex in diastole. [42] Two factors that may lead to erroneous results with cardiac TDI are an insonation angle that is not parallel or within 15^{o} of the structure being interrogated and translational motion errors related to movement of the interrogated region of interest (ROI) into and out of the Doppler beam. Despite these limitations, cardiac TDI can provide a wealth of information about regional and global myocardial systolic and diastolic function. [43]

Unlike cardiac TDI, in which contraction of the heart is usually not influenced by surrounding structures, motion of the diaphragm dome can be influenced by factors such as compliance of the rib cage and abdomen as well as by the impedance of neighbouring structures such as the liver or by the presence of pleural adhesions. Other methodologic factors that can affect diaphragm TDI are the same as those that can lead to erroneous cardiac TDI measurements. These include translation of the ROI(Range of interest) into and out of the Doppler beam and assuring that the Doppler beam is parallel to the structure being evaluated. Cardiac TDI implements algorithms and other means to mitigate these errors. Similar processes need to be considered when applying TDI to the diaphragm. [44]

The study by Soilemezi et al. reemphasizes the relationship between velocity of muscle contraction and muscle endurance [38]. Diaphragm performance can be interpreted in the construct of its Pdi–inspiratory

flow (VI) relationship, analogous to the force–velocity relationship of a contracting muscle. At a given lung volume (diaphragm length), Pdi and VI are negatively related. There is a similar trade-off between Pdi and VI for a given level of $\dot{V}O_2$. [45] Because high contraction velocities can lead to fatigue, it is not surprising that Soilemezi and colleagues found that subjects who failed weaning had higher velocities of dome motion. [10]

Monitoring diaphragm function in the ICU could help physicians to more clearly understand the interaction between the patient's effort and the ventilator. It could participate in the ventilator setting decision-making process. Ultimately, diaphragm function monitoring could be very useful in patients with difficult and prolonged weaning by predicting weaning failure and diagnosing diaphragm dysfunction. [31] Thus, we in our present study aimed to assess the role of diaphragm parameters, diaphragm excursion (DE), diaphragm thickness fraction (DTF), diaphragm excursion-time index (DETI) and tissue doppler imaging (TDI) during weaning from invasive mechanical ventilation. In this present study of ours, we have also attempted to find out cut off TDI values of: PCV (peak contraction velocity), PRV (peak relaxation velocity) and VTI (velocity time integral) of diaphragmatic muscle motion during contraction and relaxation for weaning failure from the patients who fail weaning trial. We have also attempted to find out any correlation, if present, between the TDI parameter, PCV and the M mode parameters, DE and DETI.

MATERIALS AND METHODS

SOURCE OF DATA

Study design: Prospective observational study

Study place: Intensive care units, Dayanand Medical College and Hospital, Ludhiana

Study Period: January 2022 to December 2022

METHOD OF COLLECTION OF DATA

Inclusion criteria:

1. All patients more than 18 years of age, who had been mechanically ventilated for more than 24 hours and were being planned for weaning after their cause for which they were on invasive mechanical ventilation had been resolved or was resolving.

Exclusion criteria:

1. Age <18 years
2. Neuromuscular diseases
3. Flail chest or multiple rib fractures
4. Chest tubes in place
5. Morbid obesity
6. Spinal cord injuries
7. Inability to obtain a clear TDI signal of the right hemi-diaphragm
8. Tracheostomised patients

Weaning failure definition:

- Weaning failure is defined as the failure to pass a spontaneous-breathing trial or the need for reintubation within 48 hours following extubation. [6]

Weaning success definition:

- Weaning success is considered if ventilatory support, including noninvasive ventilation, was not required for 48 hours after extubation.[6]

STUDY PROTOCOL:

The study was performed on 100 patients admitted to the ICU who were on invasive mechanical ventilation for any indication .The patients were recruited in the study when they were ready for weaning and the cause for which they were on mechanical ventilation had resolved or was resolving. The age, sex, BMI, number of days on mechanical ventilation, reason for ICU admission, any co-morbidities, SOFA score, GCS, MRC grading of muscle-power, TLC count, Haemoglobin, S.Albumin, Left-ventricular ejection-fraction, BNP levels, S.calcium, potassium, phosphorus levels , CAM-ICU guided presence or absence of delirium were all recorded on a predesigned proforma. The patients were given a trial of Pressure Support Ventilation (PS=5-10 cm water),for minimum 30 minutes with 5-10 cm water PS, and if well-tolerated, the lung mechanics parameters, RSBI(Rapid Shallow Breathing Index), NIF(Negative Inspiratory Force), P0.1(Airway Occlusion Pressure) were measured and recorded. All the diaphragm ultrasound parameters including the DE (Diaphragm Excursion), Inspiratory time(Ti), DETI(Diaphragm excursion Time Index), DTF (Diaphragm Thickness Fraction), TDI parameters including PCV (Peak Contraction Velocity, PRV (Peak Relaxation Velocity) and VTI(Velocity Time Integral) were all recorded on Pressure Support Ventilation.

Following this, patients were given a T-piece trial if they met the following criteria: appropriate mental status and cooperation, adequate oxygenation (oxygen saturation as measured by pulse oximetry at least 92%, $FIO_2 \leq 40\%$, P/F ratio >200, PEEP requirement $\leq$5cm water), hemodynamic stability with minimal vasopressor or inotropic support, and normal metabolic status, respiratory rate <30/min, relatively less secretions and improving chest imaging.

The diaphragm ultrasound examination in the ICU patients was performed at the end of a 30-minute T-piece weaning trial. Reinstitution of mechanical ventilation was initiated if signs of respiratory distress like diaphoresis, tachypnea, hypoxemia and/or hypercapnia, hemodynamic instability or altered sensorium were observed. Weaning success was considered if ventilatory support, including non-invasive

ventilation, was not required for 48 hours after weaning. However, if the patient tolerated T-piece trial, they were extubated as per the order of the primary team.

All ultrasound measurements were performed on the right hemi-diaphragm because of the limited acoustic window on the left. The DE, Ti, DETI, and TDI parameters were obtained with a phased array 2–4 MHz probe (Sonosite machine from FUJIFILM SonoSite, Inc.; Bothell, WA 98021 USA). The probe was placed in the subcostal position between the midclavicular and anterior axillary lines, with the patients breathing spontaneously laying on a bed with the head elevated at 30 degrees. As these measurements are angle dependent, the aim was that the ultrasound beam should reach perpendicularly on the middle or posterior third of the hemidiaphragm.

Diahragm thickness was measured by bedside transthoracic ultrasonography. A high-frequency (10 Mega Hertz [MHz]) linear probe was placed in cranio-caudal direction in the ninth or tenth intercostal space (zone of apposition) near the mid-axillary line and angled perpendicular to the chest wall. The diaphragm was identified as a three-layered muscular layer bounded by the membranes of the diaphragmatic pleura and peritoneum.

Diaphragmatic thickness was measured at both end-inspiration and end-expiration in a patient on SBT during tidal breathing. [46]

DTF= (TI − TE/TE) × 100 (Where TI is thickness at end inspiration, TE is the thickness at end expiration) and DTF is Diaphragm Thickness Fraction.

The sample volume for TDI was initially selected at 5mm and occasionally adjusted to incorporate the whole range of diaphragmatic motion. The velocity scale to be used was 5 cm/sec to match the lower velocity of the moving diaphragm compared with that of the beating heart. Four- six breaths per subject were saved for subsequent quantitative analysis.

On each TDI waveform, the following parameters were identified and measured:

1. Peak contraction velocity (PCV), defined as the maximal diaphragmatic velocity during contraction, measured in cm/s;
2. Velocity–time integral (VTI), defined as the area under the TDI curve during inspiration, measured in (cm/s)
3. Peak relaxation velocity (PRV), defined as the maximal diaphragmatic velocity during relaxation, measured in cm/s

Each of the above mentioned diaphragm ultrasound parameters were measured on Pressure- support ventilation, after 30 minutes of T-piece trial and after 24 hrs of extubation. To mitigate interobserver variability, a single intensivist was involved in taking measurements of all the patients. An average of three readings was taken to mitigate the effect of intra-observer variability. The investigator was not involved in the actual treatment or weaning of the patients and also the treating teams of the patients were blinded to ultrasound measurements.

All the recruited patients were followed up for 48 hours of extubation to look for weaning failure and the outcome was recorded.

STATISTICAL ANALYSIS:

SAMPLE SIZE ESTIMATION:

It is assumed that the failure rate is 27% based on Reference study- Palkar et al 2018. [35]

Assumptions:

Confidence Level = 95%

Precision (d) = ± 9%

For estimation of sample size, the following formula has been used

$n = (Z^2\alpha \text{ X } P \text{ X } (1-P))/d^2$

Where;

Zα = Value of standard normal variate corresponding to α level of significance

P = Likely value of parameter

Q = 1 – P

d = Margin of errors which is a measure of precision

With these assumptions the sample size works out as 93.

In order to make up for any loss to follow up, we enrolled a total of 100 patients in our study.

Data were described in terms of range; mean ±standard deviation (± SD), median, frequencies (number of cases) and relative frequencies (percentages) as appropriate. To determine whether the data were normally distributed, a Kolmogorov-Smirnov test was used. Comparison of quantitative variables between the study groups was done using Student t-test and Mann Whitney *U* test for independent samples for parametric and non-parametric data respectively. For comparing categorical data, Chi square ($\chi 2$) test was performed and fisher exact test was used when the expected frequency is less than 5.Covariates obtaining a P value <0.05 in the univariate analyses were included in the multivariate Binary logistic regression analyses. Spearman's rho correlation was measured. Receiver operator characteristics (ROC) curve was done, and criterion value was estimated depending on the specificity and sensitivity. Area under curve (AUC) was measured. A probability value (*p* value) less than 0.05 was considered statistically significant. All statistical calculations were done using (Statistical Package for the Social Science) SPSS 21version (SPSS Inc., Chicago, IL, USA) statistical program for Microsoft Windows.

OBSERVATIONS AND RESULTS

A total number of 124 patients admitted to intensive care units of the hospital were screened for eligibility. Out of 124 patients screened, 4 patients did not give consent, 20 patients met exclusion criteria. Hence, 100 patients were analyzed during the 12 months study period.

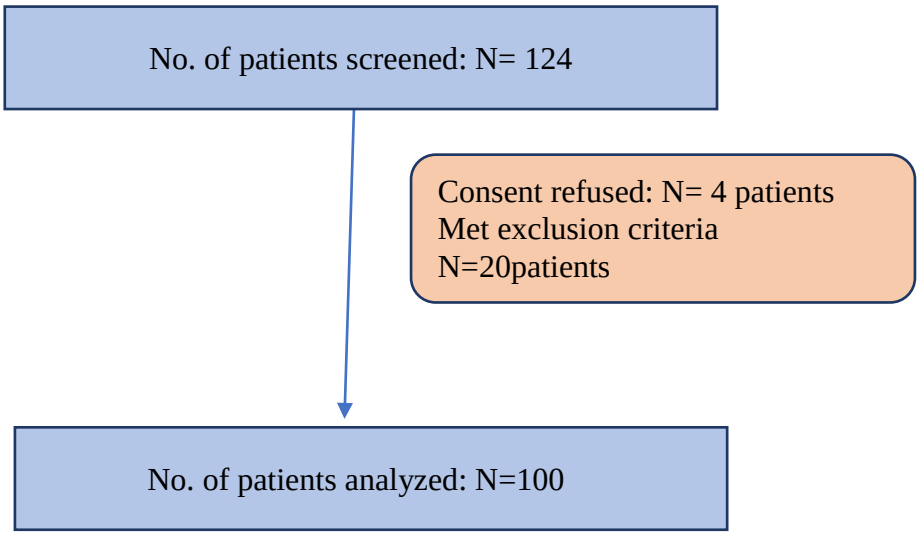
No. of patients screened: N= 124
Consent refused: N= 4 patients
Met exclusion criteria
N=20patients
No. of patients analyzed: N=100

Figure 1: STUDY PROFILE

Data depicted as N= number

We divided our patients in 2 groups on the basis of their weaning success or failure. 76 patients succeeded and 24 patients failed the weaning trial.

AGE DISTRIBUTION OF PATIENTS:

TABLE 1. AGE DISTRIBUTION OF TOTAL PATIENTS

AGE GROUP	No. of cases	Percentage
< 30	16	16.0%
31-40	24	24.0%
41-50	21	21.0%
51-60	21	21.0%
61-70	14	14.0%
> 70	4	4.0%
Total	100	100.0%

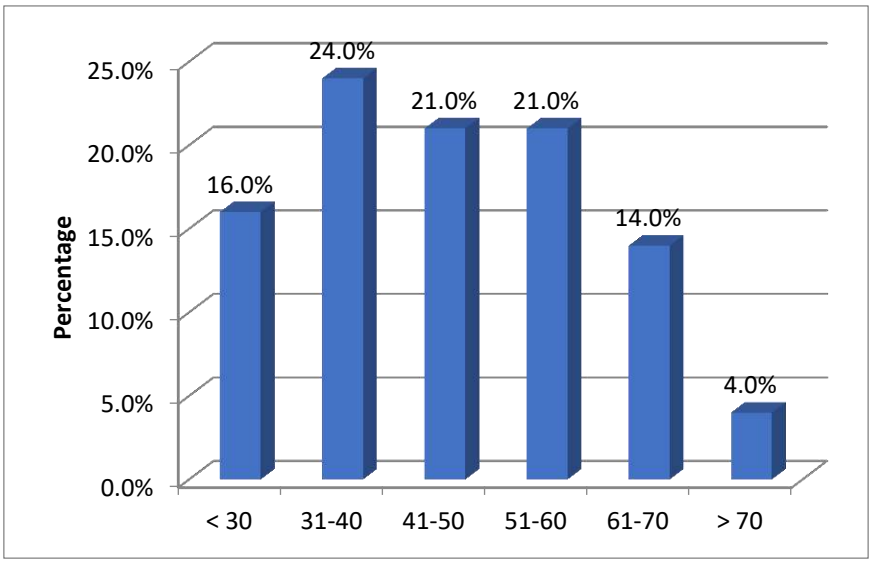

FIGURE 2. AGE DISTRIBUTION OF TOTAL PATIENTS

Out of total 100 patients that were recruited, 16 patients were in the age group <30 years, 24 were between 31-40 years , 21 patients were between 41-50 years age group, 21 were between 51-60 years, 14 patients were in 61-70 years age group and only 4 patients were >70 years old.

TABLE 2.GENDER DISTRIBUTION OF TOTAL PATIENTS

SEX	No. of cases	Percentage
F	36	36.0%
M	64	64.0%
Total	100	100.0%

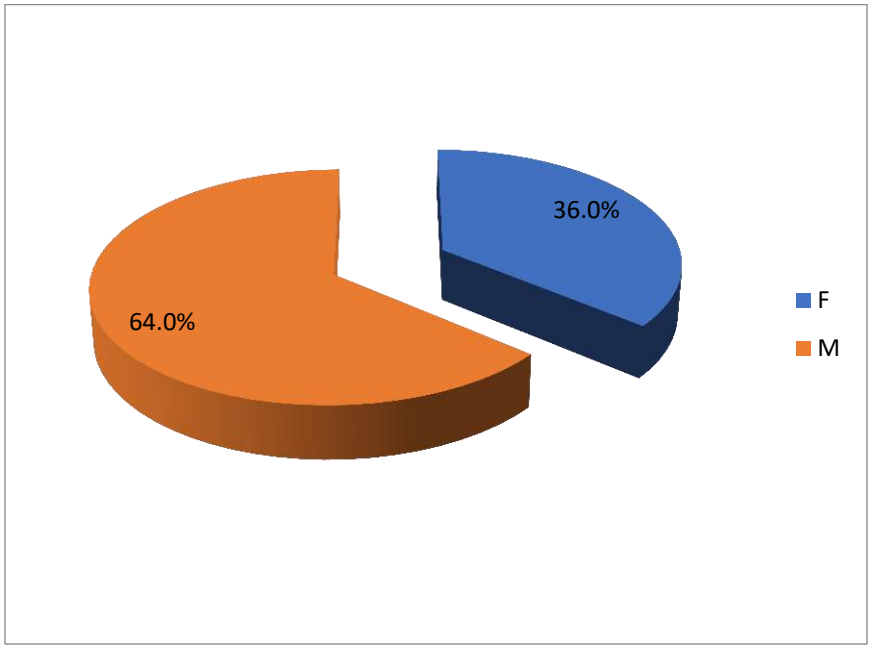

FIGURE 3.GENDER DISTRIBUTION OF TOTAL PATIENTS

Out of total 100 patients that were recruited,36 were females and 64 were males.

TABLE 3. BMI DISTRIBUTION OF TOTAL PATIENTS

BMI GROUP(kg/m2)	No. of cases	Percentage
< 18.5	3	3.0%
18.5-22.9	13	13.0%
23-24.9	29	29.0%
25-29.9	40	40.0%
30-35	14	14.0%
> 35	1	1.0%
Total	100	100.0%

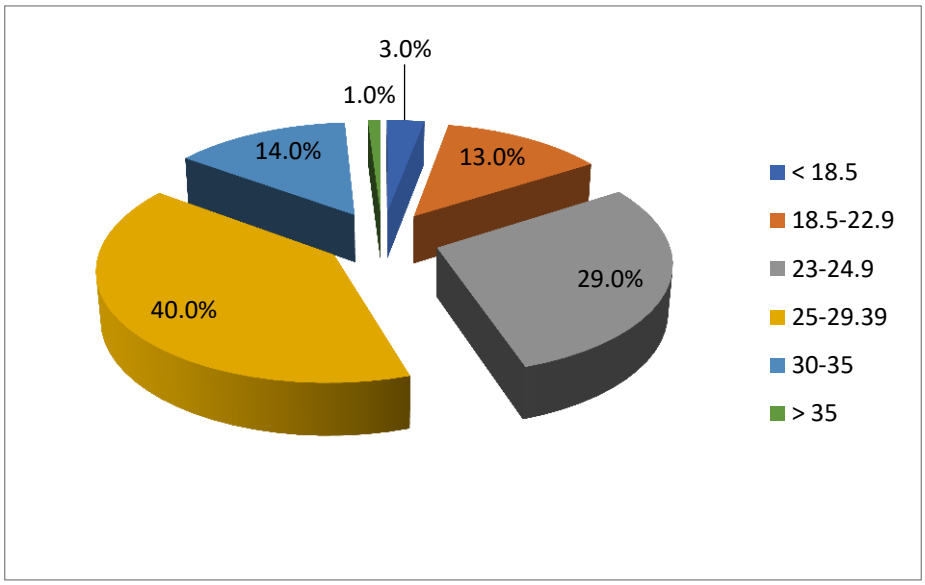

FIGURE 4. BMI DISTRIBUTION OF TOTAL PATIENTS

Out of total 100 patients that were recruited, 3 were underweight, 13 had BMI of 18.5-22.9 kg/m^2, 29 had BMI of 23-24.9 kg/m^2, 40 had BMI of 25-29.9kg/m^2, 14 were class 1 obese and one patient was class 2 obese.

TABLE 4. DISTRIBUTION OF CO MORBIDITIES AMONGST ALL PATIENTS

CO MORBIDITIES	No. of cases	Percentage
no	79	79.0%
CKD	2	2.0%
CLD	2	2.0%
Hypothyroidism	3	3.0%
COPD	2	2.0%
Dengue	1	1.0%
DM	10	10.0%
R sided gross pleural effusion	1	1.0%
HTN	9	9.0%

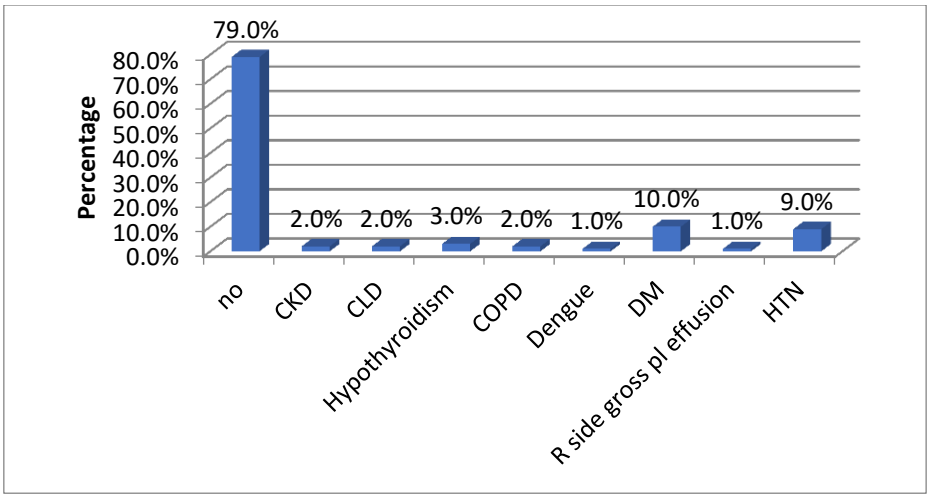

FIGURE 5. DISTRIBUTION OF CO MORBIDITIES AMONGST ALL PATIENTS

Out of total 100 patients that were recruited, 79 patients had no comorbidities, 10 were diabetic(Type 2 Diabetes Mellitus), 9 were hypertensive, 3 had hypothyroidism, 2 had CKD (Chronic Kidney Disease), 2 had CLD (Chronic Liver Disease), 2 had COPD (Chronic Obstructive Pulmonary Disease), 1 patient was Dengue NS1Antigen positive and 1 patient had gross right sided pleural effusion.

TABLE 5. DISTRIBUTION OF SOFA (SEQUENTIAL ORGAN FAILURE ASSESSMENT) SCORES AMONGST ALL PATIENTS

SOFA	No. of cases	Percentage
2	11	11.0%
3	16	16.0%
4	12	12.0%
5	8	8.0%
6	14	14.0%
7	21	21.0%
8	10	10.0%
9	7	7.0%
10	1	1.0%
Total	100	100.0%

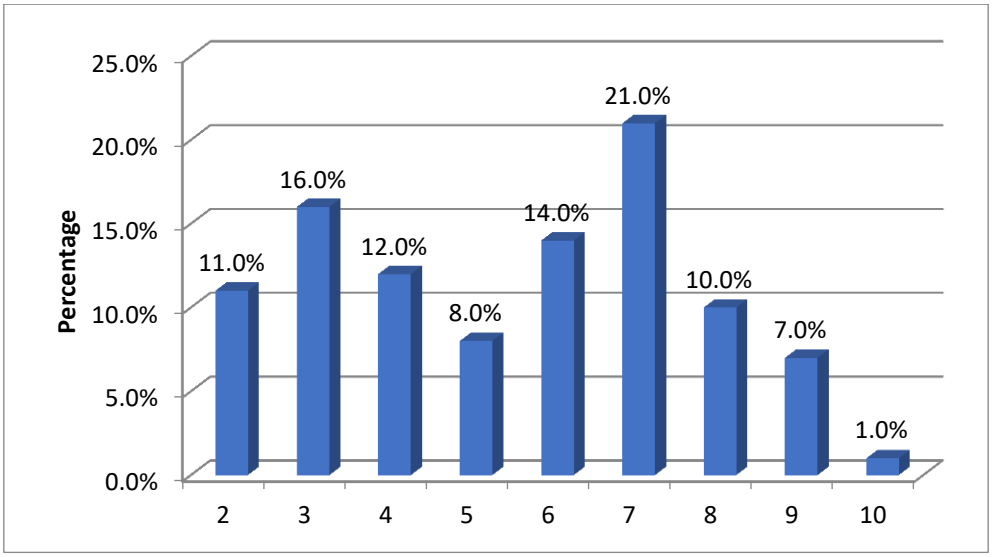

FIGURE 6. DISTRIBUTION OF SOFA (SEQUENTIAL ORGAN FAILURE ASSESSMENT) SCORES AMONGST ALL PATIENTS

In the figure 4, the X axis shows SOFA scores and Y axis shows percentage distribution. SOFA score was calculated to be 7 in the maximum number of patients (21 patients), followed by SOFA score of 3 in 16 patients followed by score of 6 in14 patients. Figure 4 depicts the SOFA score of all 100 patients.

TABLE 6. DISTRIBUTION OF GCS (GLASGOW COMA SCALE) AMONGST ALL PATIENTS

GCS	No. of cases	Percentage
8	3	3.0%
9	6	6.0%
10	6	6.0%
11	85	85.0%
Total	100	100.0%

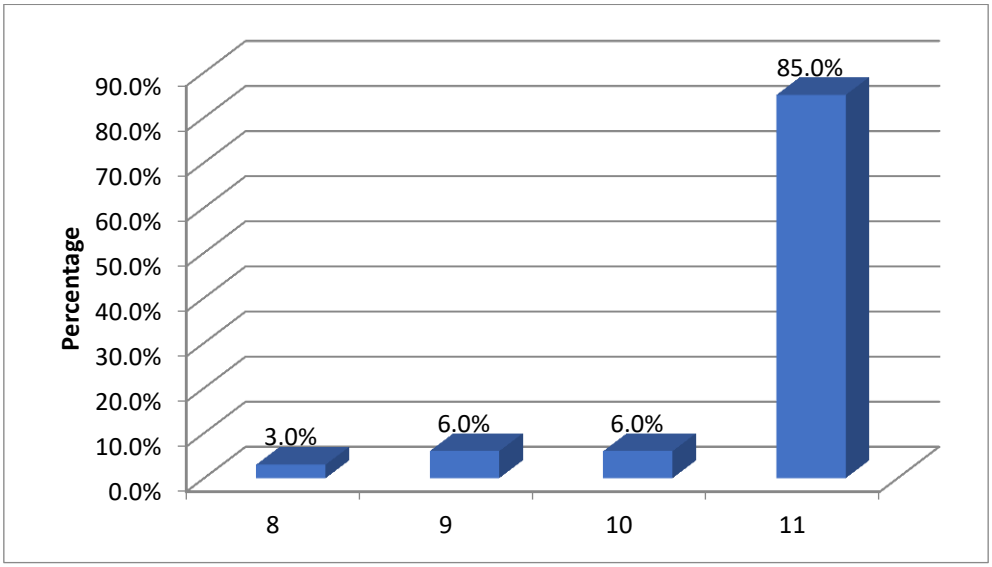

FIGURE 7. DISTRIBUTION OF GCS (GLASGOW COMA SCALE) AMONGST ALL PATIENTS

Out of total 100 patients that were recruited, maximum number of patients i.e 85 patients had a GCS of 11. The Verbal(V) component of GCS was taken as 1 as the patients were intubated. GCS of 9 and 10 were recorded in 6 patients each while GCS of 8 was recorded for 3 patients.

TABLE 7. DISTRIBUTION OF DELIRIUM AMONGST ALL PATIENTS

CAM ICU	No. of cases	Percentage
NA	16	16.0%
neg	52	52.0%
pos	32	32.0%
Total	100	100.0%

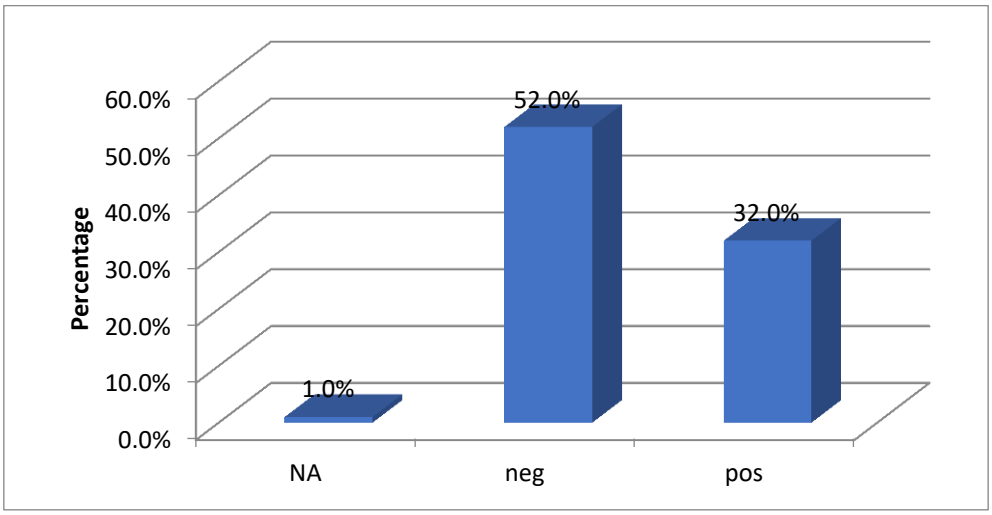

FIGURE 8. DISTRIBUTION OF DELIRIUM AMONGST ALL PATIENTS

Delirium assessment was done using the CAM-ICU (Confusion Assessment Method for the Intensive Care Unit) tool.

Out of total 100 patients that were recruited, CAM-ICU assessment could not be done on 16 patients due to lack of co-operation or low GCS. Among the remaining 84 patients, 52 patients had delirium and 32 did not have delirium.

TABLE 8. WEANING OUTCOMES AMONGST ALL PATIENTS

OUTCOME	No. of cases	Percentage
FAILURE	24	24.0%
SUCCESS	76	76.0%
Total	100	100.0%

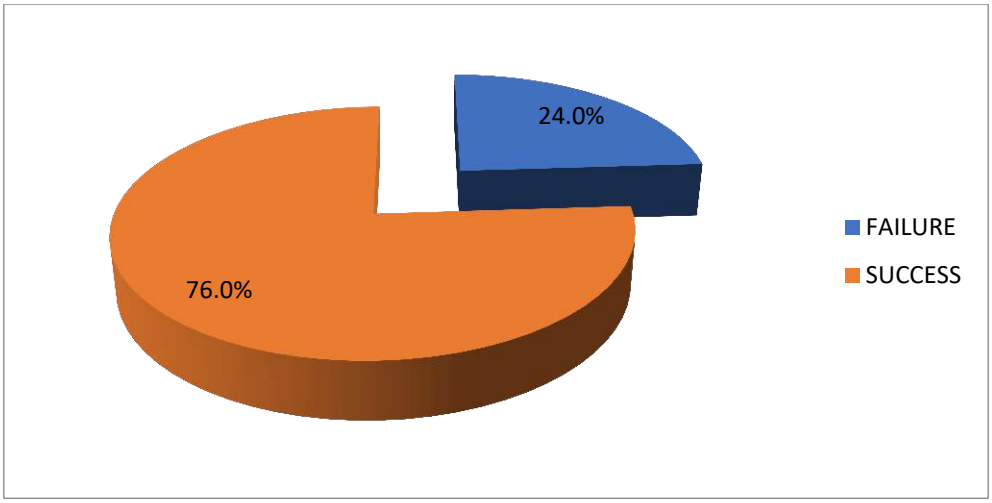

FIGURE 9. WEANING OUTCOMES AMONGST ALL PATIENTS

Out of total 100 patients that were recruited, 76 patients succeeded whereas 24 patients failed the weaning trial.

The above mentioned baseline characteristics were also compared between the patients who had weaning success and weaning failure.

TABLE 9. AGE GROUPS DISTRIBUTION AMONGST SUCCESS AND FAILURE GROUPS

	OUTCOME	FAILURE	% of cases in failure group	SUCCESS	% of cases in success group	Total	Chi-square value	p-value
AGE GROUP	< 30	2	8.3%	14	18.4%	16	6.602	0.252
	31-40	4	16.7%	20	26.3%	24		
	41-50	4	16.7%	17	22.4%	21		
	51-60	6	25.0%	15	19.7%	21		
	61-70	6	25.0%	8	10.5%	14		
	> 70	2	8.3%	2	2.6%	4		
Total		24	100.0%	76	100.0%	100		

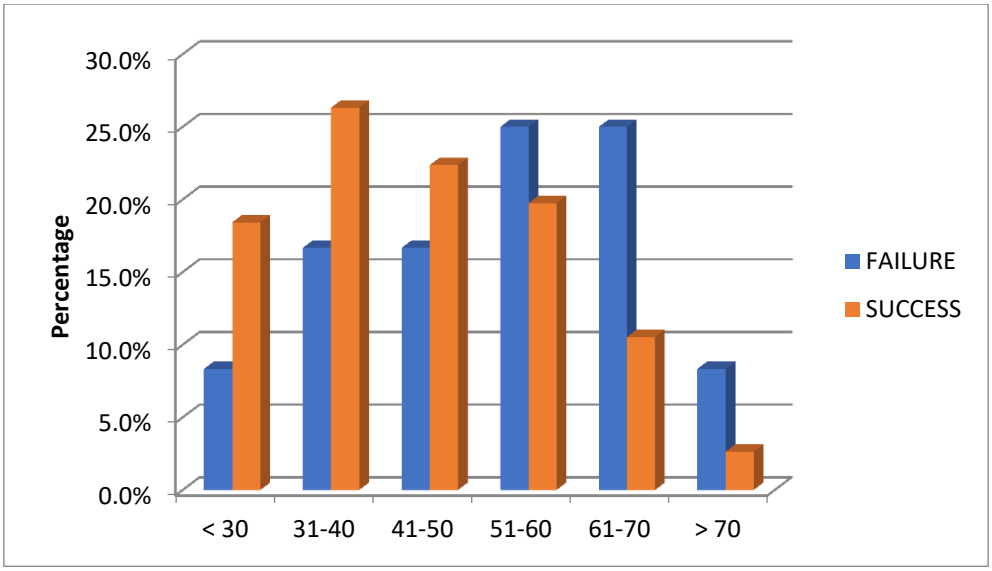

FIGURE 10. AGE GROUPS DISTRIBUTION AMONGST SUCCESS AND FAILURE GROUPS

In the failure group, 25% patients were in the age group of 51-60 years and 25% were in the age group of 61-70 years. The age groups of 31-40 and 41-50 years had 16.7 % of patients in each of these age groups In the success group, 26.3% patients were in the age group of 31-40 years, 22.4% patients were in the age group of 41-50 years and 19.7% patients were in 51-60 years age group. Although apparently the failure group had more number of patients in the older age groups, the difference between the 2 groups in terms of age was not statistically significant (p=0.252).

TABLE 10. AGE STRATIFICATION (AGE < or > 50 YEARS) AND DISTRIBUTION AMONGST SUCCESS AND FAILURE GROUPS

	OUTCOME	FAILURE		SUCCESS		Total	Chi-square value	p-value
		No. of cases	%age	No. of cases	%age			
AGE (years)	< 50	10	41.7 %	51	67.1 %	61	4.962	0.032
	> 50	14	58.3 %	25	32.9 %	39		
	Total	24	100%	76	100%	100		

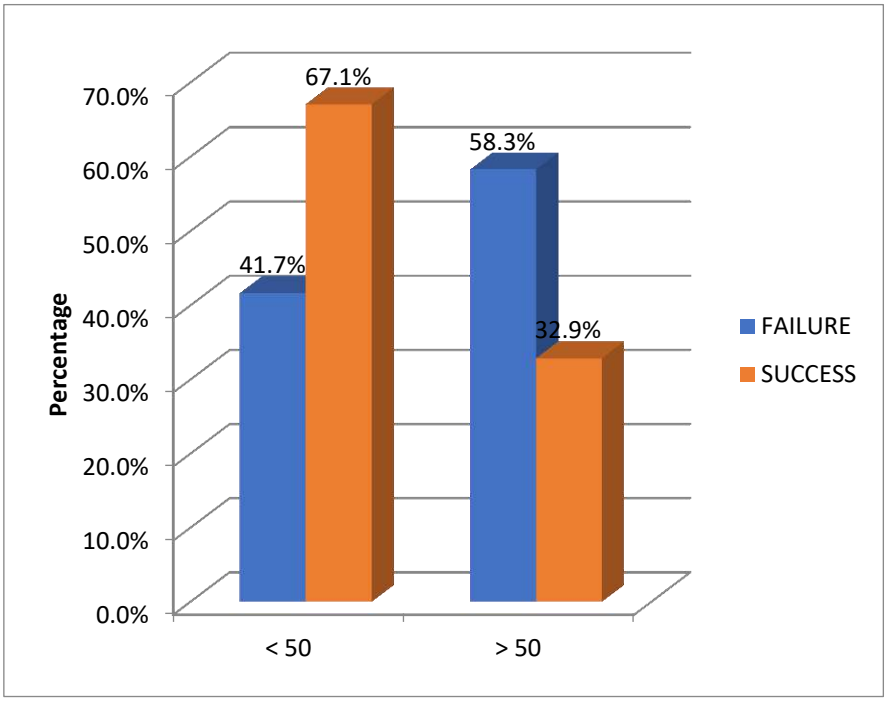

FIGURE 11. AGE – DEPENDANT COMPARISON AMONGST SUCCESS AND FAILURE GROUPS STRATIFYING FOR PATIENT AGE < or > 50 YEARS

On comparison of patients with respect to age, a greater number of patients who failed the weaning trial, were in the older age group, i.e age >50 years, upon age-stratification.

TABLE 11. GENDER DISTRIBUTION AMONGST SUCCESS AND FAILURE GROUPS

	OUTCOME	FAILURE		SUCCESS		Total	Chi-square value	p-value
		No. of cases	%age	No. of cases	%age			
SEX	F	9	37.5 %	27	35.5 %	36	0.03	0.861
	M	15	62.5 %	49	64.5 %	64		
Total		24	100.0 %	76	100.0 %	100		

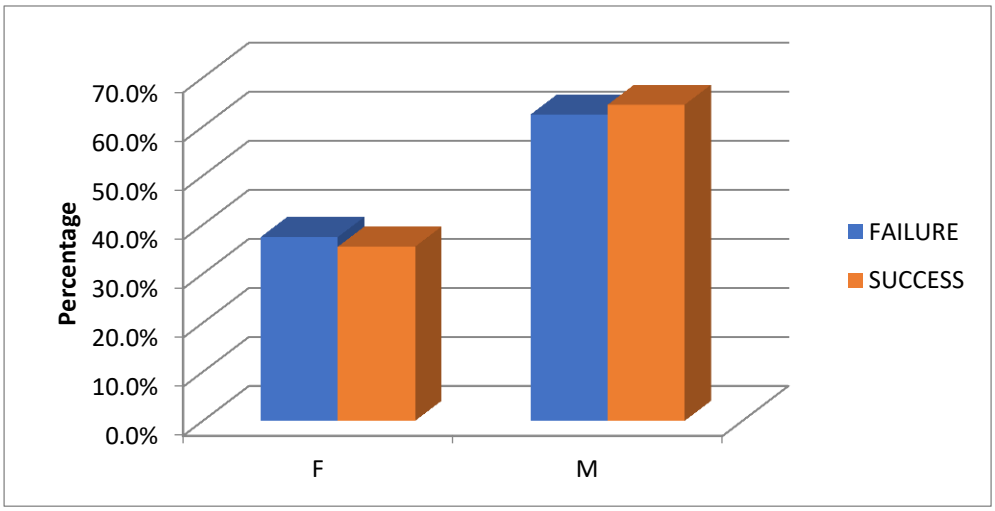

FIGURE 12. GENDER DISTRIBUTION AMONGST SUCCESS AND FAILURE GROUPS

There were 62.5% male patients in failure group and 64.5% male patients in the success group. There was no statistically significant difference between the 2 groups with respect to gender distribution (p=0.861).

TABLE 12. BMI DISTRIBUTION AMONGST WEANING SUCCESS AND FAILURE GROUPS.

BMI GROUPS (kg/m^2)	Outcome	Failure	Percentage	Success	Percentage	Total	Chi-Square Value	P-Value
		No. Of Cases		No.Of Cases				
	< 22.9	2	8.3%	14	18.4%	16	2.179	0.824
	23-24.9	8	33.3%	21	27.6%	29		
	25-29.39	10	41.7%	30	39.5%	40		
	30-35	4	16.7%	10	13.2%	14		
	> 35	0	0.0%	1	1.3%	1		
Total		24	100.0%	76	100.0%	100		

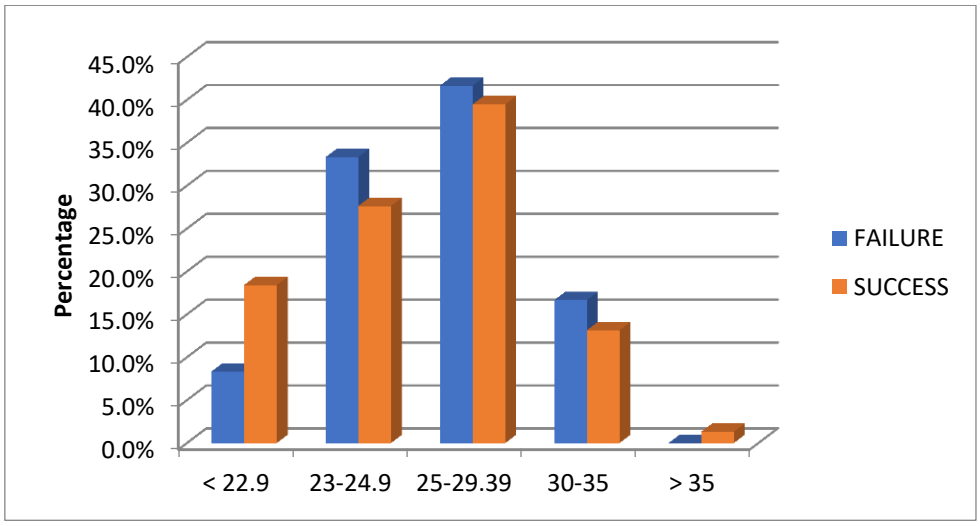

FIGURE 13. BMI DISTRIBUTION AMONGST WEANING SUCCESS AND FAILUREGROUPS

There was no statistically significant difference between the 2 groups with respect to BMI of the patients (p=0.824).

TABLE 13. DISTRIBUTION OF CO-MORBIDITIES AMONGST WEANING SUCCESS AND FAILURE GROUPS.

	OUTCOME	FAILURE	FAILURE	SUCCESS	SUCCESS	Total	Chi-square value	p-value
CO MORBIDITIES	NO	15	62.5%	64	84.2%	79	25.337	0.013
	CKD	2	8.3%	0	0.0%	2		
	CLD	2	8.3%	0	0.0%	2		
	Hypothyroidism	2	8.3%	1	1.3%	3		
	COPD	1	4.2%	1	1.3%	2		
	Heart failure	0	0.0%	1	1.3%	1		
	DM	5	20.8%	5	6.6%	10		
	R side gross pl effusion	1	4.2%	0	0.0%	1		
	HTN	4	16.7%	5	6.6%	9		

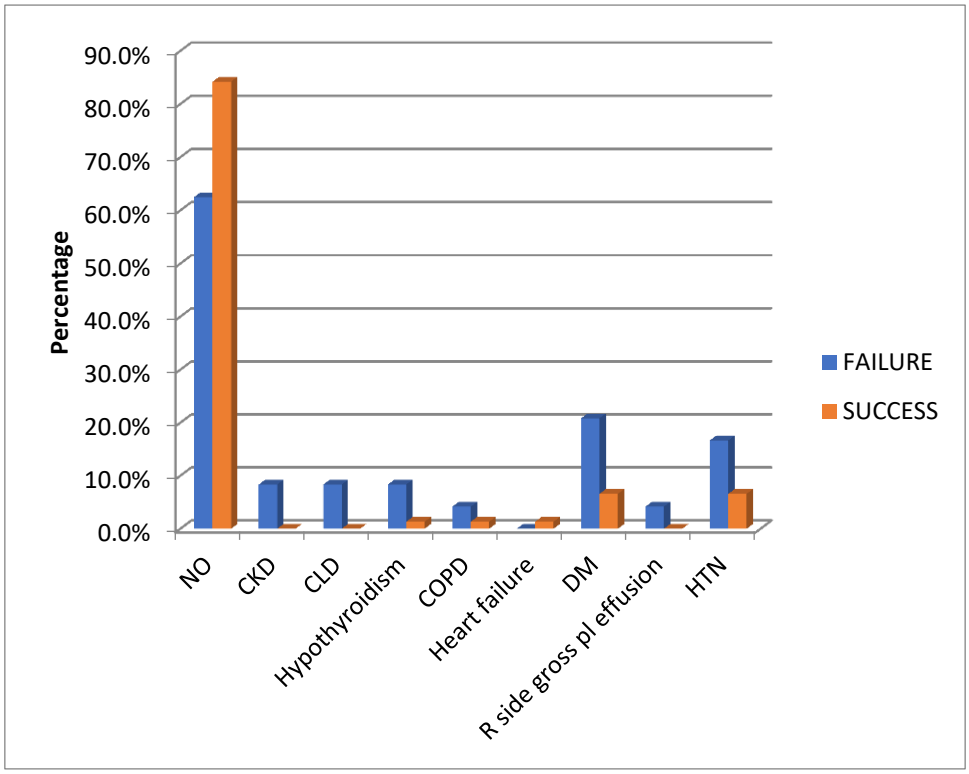

FIGURE 14. DISTRIBUTION OF CO-MORBIDITIES AMONGST WEANING SUCCESS AND FAILURE GROUPS.

A greater proportion of patients in the weaning failure group had co-morbidities (37.5%) as compared to the success group (15.8%). This difference was statistically significant (p =0.013).

TABLE 14. DISTRIBUTION OF DELIRIUM AMONGST WEANING SUCCESS AND FAILURE GROUPS.

	OUTCOME	FAILURE NO.	Percentage	SUCCESS No.	Percentage	Total	Chi-square value	p-value
CAM ICU	NA	3	12.5%	13	17.1%	16	10.457	**0.015**
	neg	7	29.2%	45	59.2%	52		
	pos	14	58.3%	18	23.7%	32		
Total		24	100.0%	76	100.0%	100		

The incidence of delirium was higher in the weaning failure group (58.3%) versus the weaning success group (23.7%) and this difference was statistically significant (p=0.015).

TABLE 15. COMPARISON OF ALL BASELINE CHARACTERISTICS BETWEEN THE 2 GROUPS.

	FAILURE		SUCCESS		Z	p-value
	Mean	**SD**	**Mean**	**SD**		
AGE (years)	52.46	13.55	44.32	14.07	-2.425	**0.015**
BMI (kg/m2)	26.09	3.47	25.56	3.76	-0.474	0.636
DAYS ON MV	10.04	3.95	4.91	2.61	-5.303	**0.001**
SOFA	6.75	1.80	5.00	2.17	-3.389	**0.001**
GCS	10.79	0.66	10.71	0.73	-0.429	0.668
MRC MUSCLE POWER	4.36	0.73	4.76	0.46	-2.682	**0.007**
RSBI	48.63	12.84	42.39	11.86	-1.905	0.057
P0.1(cm water)	3.33	1.58	3.03	0.86	-0.688	0.491
NIF (cm water)	-20.70	4.34	-24.45	2.34	-3.757	**0.001**
TLC	12.98	2.90	13.34	3.46	-0.130	0.896
HB(g/dl)	8.90	1.06	9.05	1.54	-0.227	0.820
ALBUMIN(g/dl)	2.79	0.63	2.89	0.47	-1.017	0.309
EF(%)	55.13	8.92	58.18	5.47	-2.026	0.045
BNP	152.92	223.71	62.26	20.99	-2.215	**0.027**
S.CALCIUM(mg/dl)	8.14	0.52	8.28	0.75	-1.589	0.112
POTASSIUM(mmol/L)	3.93	0.50	3.82	0.52	-1.163	0.245
PHOSPHORUS(mg/dl)	3.18	1.42	2.69	0.89	-1.566	0.117

Amongst all the baseline parameters (mentioned in table 12), when compared between the weaning failure and success groups there was a significant difference in terms of age, days on MV, SOFA score, muscle power, NIF and BNP. There was a significant (p=0.015) difference between the 2 groups in terms of age, with the mean age being 52.46 ± 13.55 years in failure group and 44.32±14.07 years in success group.

No. of days on mechanical ventilation were significantly (p=0.001) higher in failure group than the success group,10.79±3.95 days versus 4.91±2.61 days respectively.

The SOFA score was significantly (p=0.001)higher in the failure group 6.75±1.80 versus 5.00 ±2.17 in the success group.

The MRC grading of muscle power was significantly (p=0.007) lower in failure group 4.36+/-0.73 versus 4.76+/-0.46 in success group.

The lung mechanics parameter, NIF (Negative Inspiratory Force) was significantly (p=0.001) higher in success group -24.45±2.34 cm water versus -20.70±4.34 cm water in the failure group.

The BNP was also significantly higher in failure group 152.92+/-8.92 versus 62.26 +/- 20.99 in the success group (p=0.027).

There was no significant difference between the 2 groups in terms of BMI, GCS, RSBI (Rapid Shallow Breathing Index), P0.1 (Occlusion Pressure), TLC (Total Leukocyte Count), hemoglobin, S. albumin, ejection fraction, S. calcium, potassium and phosphorus.

TABLE 16. MULTIVARIATE REGRESSION ANALYSIS OF ALL BASELINE CHARACTERISTICS BETWEEN THE 2 GROUPS

	p-value	Odd ratio	95% C.I. for Odds' ratio	
			Lower	Upper
AGE years	0.457	1.023	0.964	1.085
DAYS ON MV	**0.001**	1.567	1.235	1.989
SOFA	0.779	0.943	0.626	1.421
MRC MUSCLE POWER	0.966	0.963	0.170	5.455
NIF	**0.014**	1.478	1.084	2.017
BNP	0.275	1.009	0.993	1.024

Among all baseline characteristics that were statistically significant on univariate analysis, a multivariate regression analysis was done which showed that a longer duration of mechanical ventilation had 1.6 times higher odds of weaning failure (OR 1.567, p=0.001) Also, lower NIF had 1.48 times higher odds of weaning failure (OR= 1.478, p=0.014), while age, SOFA score, muscle power and BNP were statistically insignificant.

TABLE 17. COMPARISON OF THE DIFFERENT DIAPHRAGM USG PARAMETERS ON PRESSURE SUPPORT MODE OF MECHANICAL VENTILATION

	FAILURE		SUCCESS		Z	p-value
	Mean	SD	Mean	SD		
ON MV (PS/CPAP) **DE (cm)**	1.02	0.35	1.59	0.34	-5.943	**0.001**
ON MV(PS/CPAP)**INSPIRATORY TIME(Ti) sec**	0.90	0.30	1.00	0.21	-2.652	**0.008**
ON MV (PS/CPAP) **DETI(cmsec)**	0.94	0.49	1.58	0.46	-5.368	**0.001**
ON MV(PS/CPAP) **DTF(%)**	22.93	18.09	43.14	24.06	-5.433	**0.001**
ON MV (PS/CPAP) **PCV (cm/s)**	3.23	0.68	2.35	0.90	-4.442	**0.001**
ON MV (PS/CPAP) **PRV(cm/s)**	3.09	0.90	2.22	0.84	-4.144	**0.001**
ON MV (PS/CPAP) **VTI (cm)**	1.69	0.86	1.32	0.54	-1.635	0.102

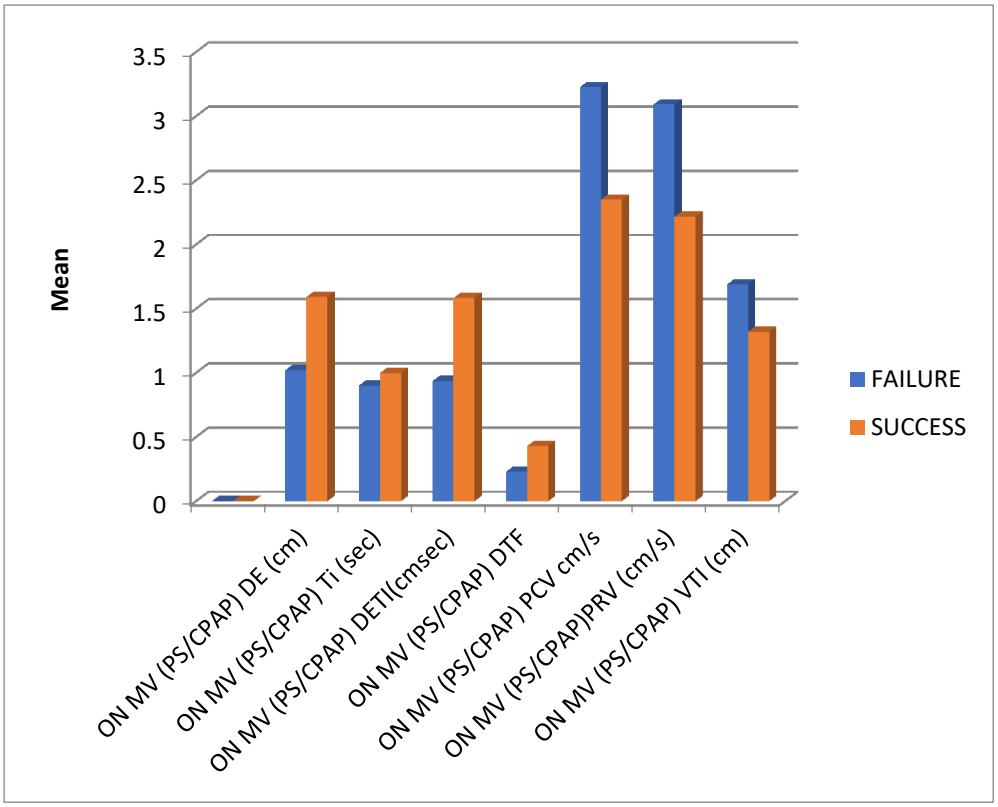

FIGURE 15. COMPARISON OF THE DIFFERENT DIAPHRAGM USG PARAMETERS ON PRESSURE SUPPORT MODE OF MECHANICAL VENTILATION

The mean DE was 1.02±0.35 cm in the failure group versus 1.59±0.34cm in success group on PS/CPAP mode of MV (p=0.00. The Ti in failure group was 0.90±0.30 s versus 1.00±0.21 s in the success group on PS/CPAP mode (p=0.008).

The mean value of DETI on PS/CPAP mode, in failure group was 0.94±0.49 cm s vs 1.58±0.46 cm s in success group (p=0.001).

The mean DTF in failure group was 22.93±18.09% versus 43.14± 24.06% in success group (p=0.001).

The TDI parameters in our study, on PS/CPAP mode of MV were mean PCV in failure group 3.23±0.68 cm/s versus 2.35±0.90 cm/s in success group (p=0.001). The mean PRV in failure vs success groups was 3.09±0.90 cm/s vs 2.22±0.84 cm/s (p=0.001). The mean VTI was 1.69±0.86 cm/s in failure group vs 1.32±0.54 cm/s in success group (p=0.102).There is a significant difference between all the above mentioned parameters in the success and failure groups except for the TDI parameter, VTI (Velocity Time Integral). For graphical representation, DTF has been presented as a fraction and not as percentage.

TABLE 18. COMPARISON OF THE DIFFERENT DIAPHRAGM USG PARAMETERS AFTER 30 MINUTES OF A T PIECE TRIAL

	FAILURE		SUCCESS		Z	p-value
	Mean	SD	Mean	SD		
30MINS OF WEANING TRAIL **DE (cm)**	1.12	0.25	1.58	0.32	-5.192	**0.001**
30 MIN WEANING TRIAL **Ti(sec)**	0.85	0.33	0.97	0.23	-2.559	**0.011**
30MINS OF WEANING TRIAL **DETI (cms)**	0.98	0.50	1.55	0.57	-4.178	**0.001**
30MINS OF WEANING TRAIL **DTF(%)**	24.53	21.10	45.87	28.70	-5.022	**0.001**
30MINS OF WEANING TRAIL **PCV (cm/s)**	3.26	0.67	2.40	0.86	-4.301	**0.001**
30MINS OF WEANING TRAIL **PRV (cm/s)**	3.20	0.93	2.32	0.89	-3.779	**0.001**
30MINS OF WEANING TRAIL **VTI (cm)**	1.74	0.91	1.41	0.52	-1.293	0.196

.

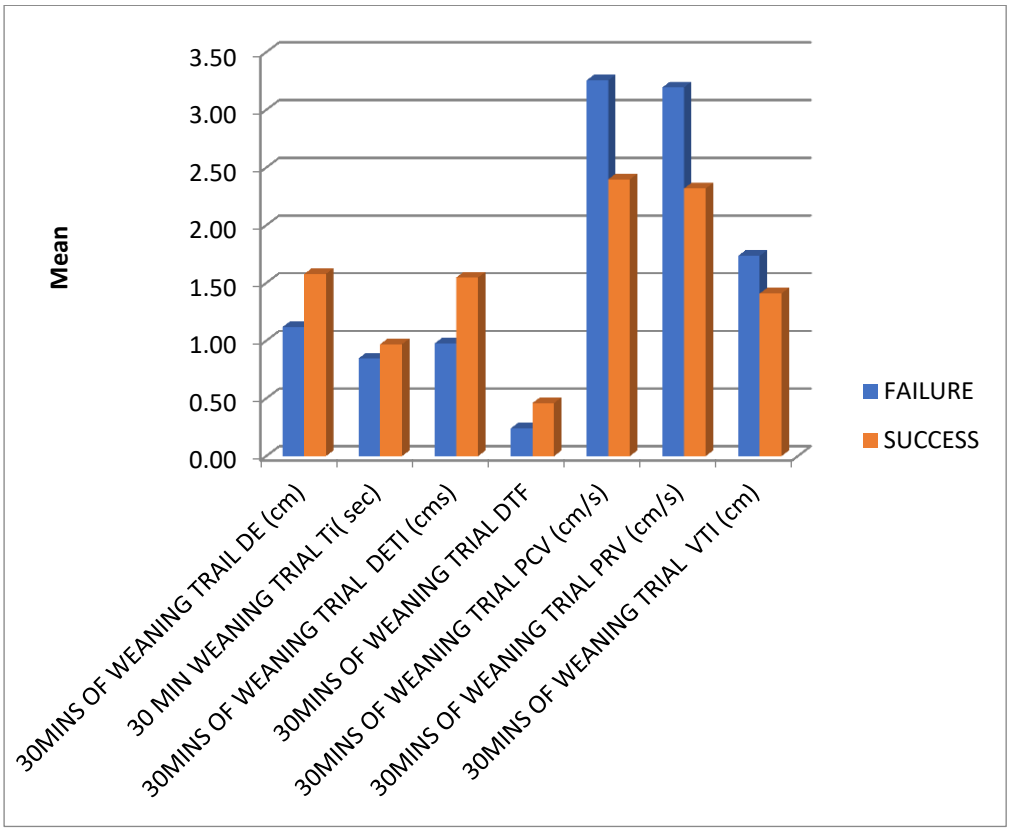

FIGURE 16. COMPARISON OF THE DIFFERENT DIAPHRAGM USG PARAMETERS AFTER 30 MINUTES OF A T PIECE TRIAL

Similar to the comparison on pressure support ventilation, all the parameters were significantly different between the 2 groups except for VTI (p=0.196). 3 patients in the failure group failed weaning even before completion of 30 minutes of weaning trial and were put back on assist controlled mode of ventilation. Thus, those 3 patients were not taken into analysis, as all these measurements had to be done on spontaneous breathing only. For graphical representation, DTF has been presented as a fraction and not as percentage.

TABLE 19. COMPARISON OF THE DIFFERENT DIAPHRAGM USG PARAMETERS AFTER 24 HRS OF WEANING TRIAL

	FAILURE		SUCCESS		Z	p-value
	Mean	SD	Mean	SD		
24 HRS OF WEANING TRIAL **DE (cm)**	0.96	.	1.79	0.33	-1.718	0.086
24 HRS WEANING **Ti (sec)**	0.60	.	1.07	0.13	-1.711	0.087
24 HRS OF WEANING TRIAL **DETI (cm s)**	0.58	.	1.91	0.42	-1.714	0.086
24 HRS OF WEANING TRIAL **DTF(%)**	45.00	.	59.19	32.39	-0.135	0.893
24 HRS OF WEANING TRIAL **PCV(cm/s)**	2.82	.	2.29	0.88	-0.992	0.321
24 HRS OF WEANING TRIAL**PRV (cm/s)**	3.69	.	2.25	0.92	-1.488	0.137
24 HRS OF WEANING TRIAL **VTI (cm)**	0.47	.	1.37	0.60	-1.712	0.087

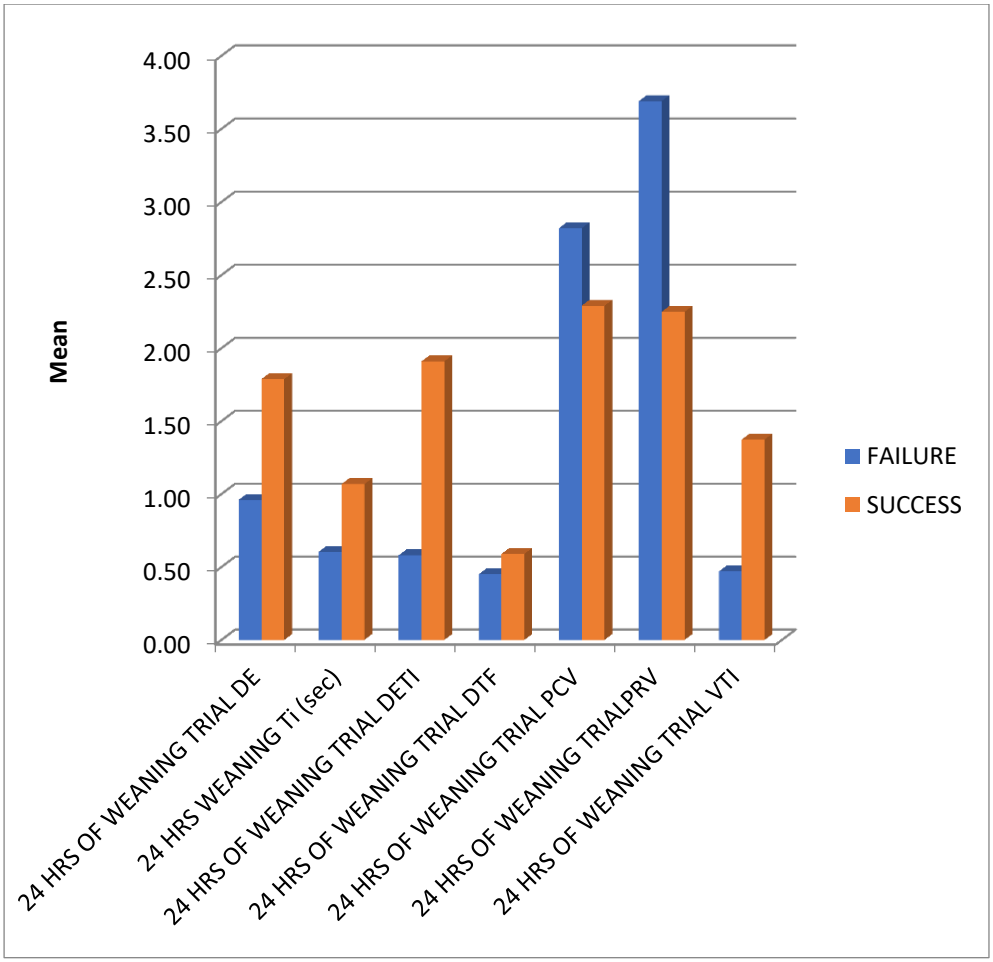

FIGURE 17. COMPARISON OF THE DIFFERENT DIAPHRAGM USG PARAMETERS AFTER 24 HRS OF WEANING TRIAL

As all the diaphragmatic parameters were to be measured on spontaneous ventilation, among the 24 patients who failed weaning,23 patients were taken on assist controlled mode within 24 hours and hence, measurements could be taken only on 1 patient who failed weaning after 24 hours. 23 patients were put back on assist controlled mode before completion of 24 hours of weaning trial, so they were not included in the analysis at this point of time, as all these measurements had to be done on spontaneous breathing. For graphical representation, DTF has been presented as a fraction and not as percentage.

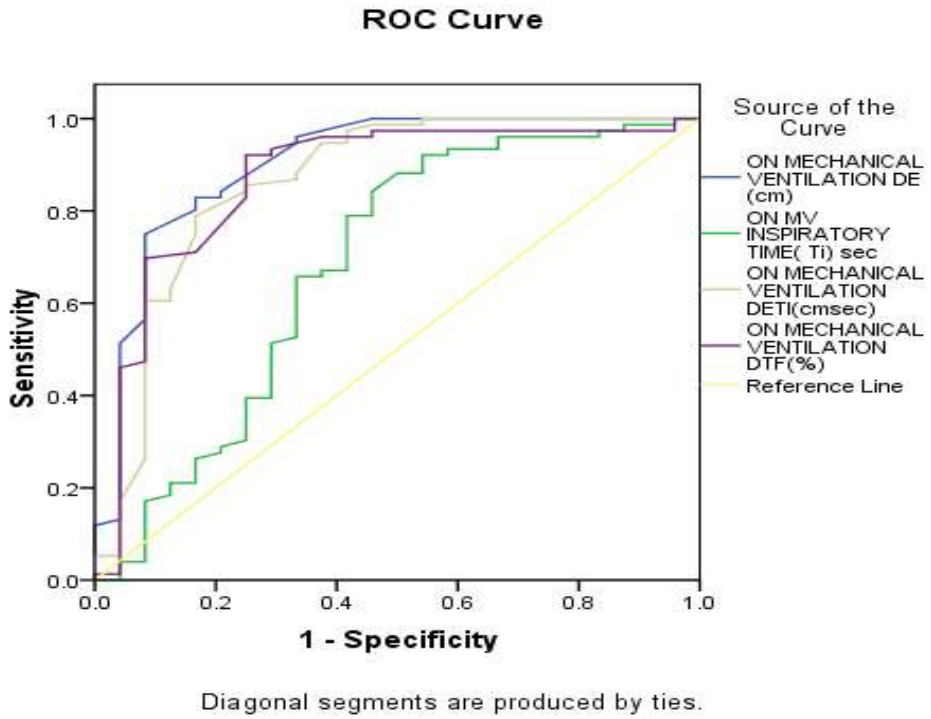

FIGURE 18. ROC CURVES FOR DE, Ti, DETI AND DTF ON PRESSURE SUPPORT MODE OF MECHANICAL VENTILATION FOR PREDICTION OF WEANING OUTCOMES

TABLE 20. AREA UNDER THE CURVE FOR ROCs OF DE, Ti, DETI, DTF ON PS/CPAP MODE OF MV

Test Result Variable(s)	AUC	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
				Lower Bound	Upper Bound
ON MECHANICAL VENTILATION DE (cm)	.903	.042	.000	.821	.985
ON MV INSPIRATORY TIME(Ti) sec	.681	.073	.008	.539	.823
ON MECHANICAL VENTILATION DETI(cmsec)	.864	.052	.000	.762	.966
ON MECHANICAL VENTILATION DTF (%)	.869	.049	.000	.773	.964

DE (Diaphragm excursion), DETI (Diaphragm excursion time index) and DTF (Diaphragm thickness fraction) show a good correlation with weaning prediction, AUC =0.903, AUC=0.864, AUC= 0.869, respectively. DE≥1.32 cm was found to be 75% sensitive and 91.7% specific for weaning success. Ti (Inspiratory time)≥0.84 seconds, was 84.2% sensitive and 54.2 % specific and

DETI≥1.24 cm, was 78.9% sensitive and 83.3% specific for weaning success. DTF≥24.5% was 89.5% sensitive and 75% specific for weaning success.

TABLE 21. DISTRIBUTION OF TDI PARAMETERS: PCV, PRV, VTI BETWEEN WEANING SUCCESS AND FAILURE GROUPS ON PS/CPAP- MV (PRESSURE SUPPORT MODE OF MECHANICAL VENTILATION)

	OUTCOME		**IQR**		P VALUE
		Median	25	75	
ON PS/CPAP (MV) PCV	FAILURE	3.20	2.83	3.80	0.001
	SUCCESS	2.10	1.80	2.88	
ON PS/CPAP (MV) PRV	FAILURE	2.90	2.44	3.88	0.001
	SUCCESS	2.20	1.70	2.50	
ON PS/CPAP (MV) VTI	FAILURE	1.45	0.95	2.48	0.102
	SUCCESS	1.23	0.89	1.73	

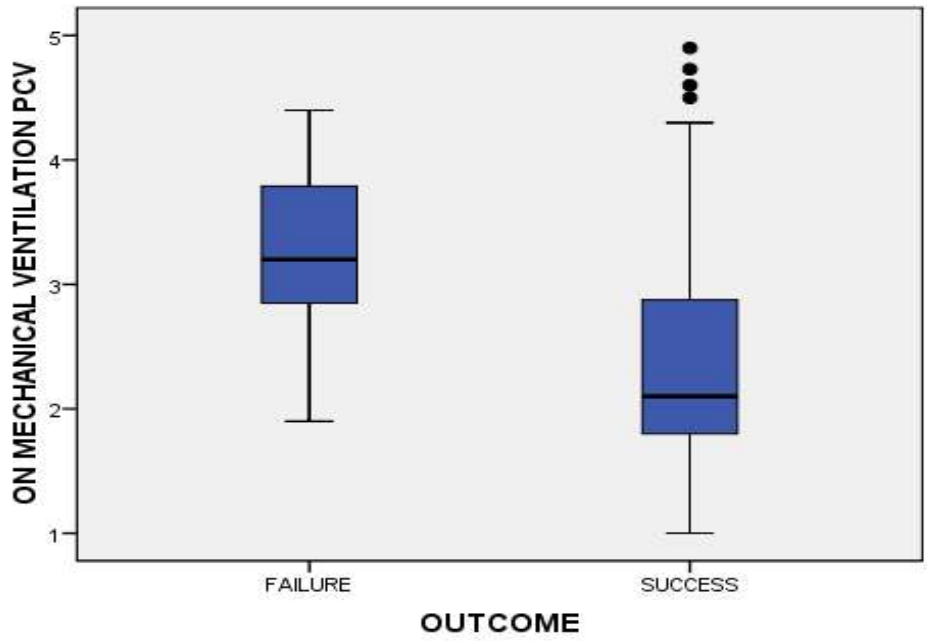

FIGURE 19. DISTRIBUTION OF PCV BETWEEN WEANING SUCCESS AND FAILURE GROUPS ON PS/CPAP- MV (PRESSURE SUPPORT MODE OF MECHANICAL VENTILATION

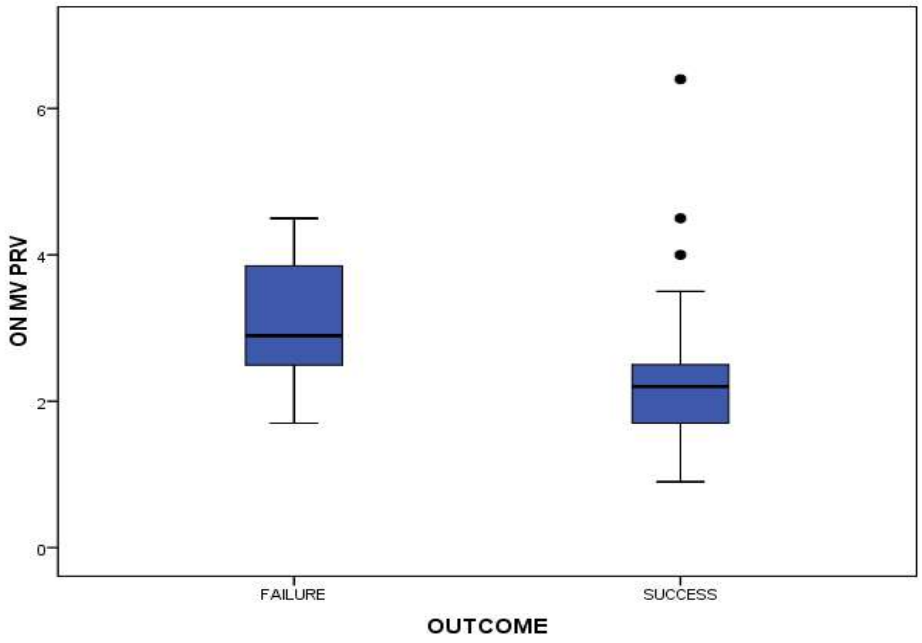

FIGURE 20. DISTRIBUTION OF PRV BETWEEN WEANING SUCCESS AND FAILURE GROUPS ON PS/CPAP- MV (PRESSURE SUPPORT MODE OF MECHANICAL VENTILATION)

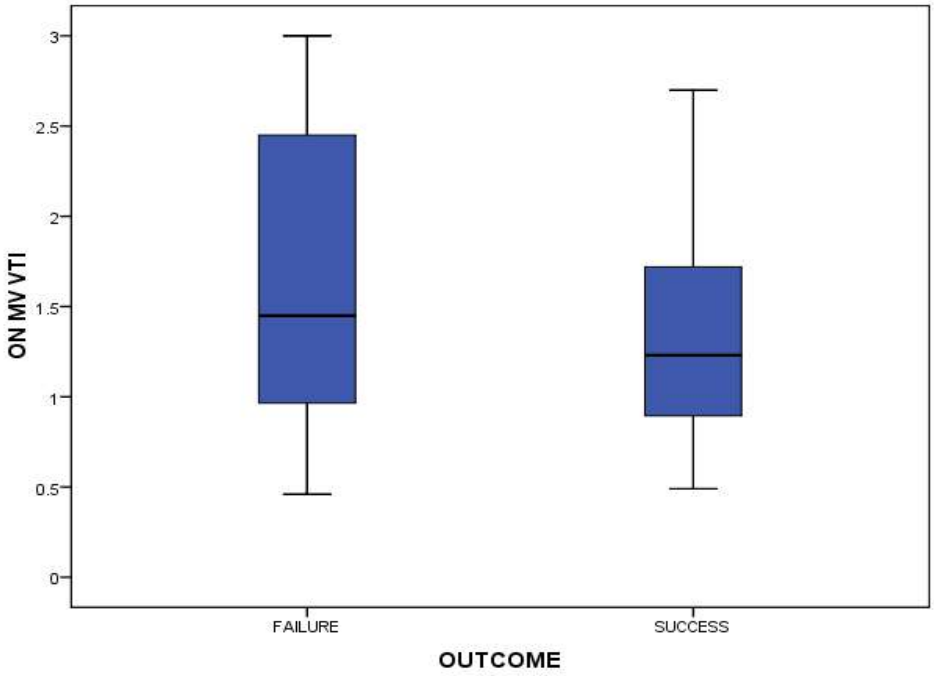

FIGURE 21. DISTRIBUTION OF VTI BETWEEN WEANING SUCCESS AND FAILURE GROUPS ON PS/CPAP-MV (PRESSURE SUPPORT MODE OF MECHANICAL VENTILATION)

There was a statistically significant difference in median PCV and PRV values on PS/CPAP mode of ventilation between the success and failure groups (p=0.001 for each). Whereas for VTI, this difference was not statistically significant, (p=0.102).

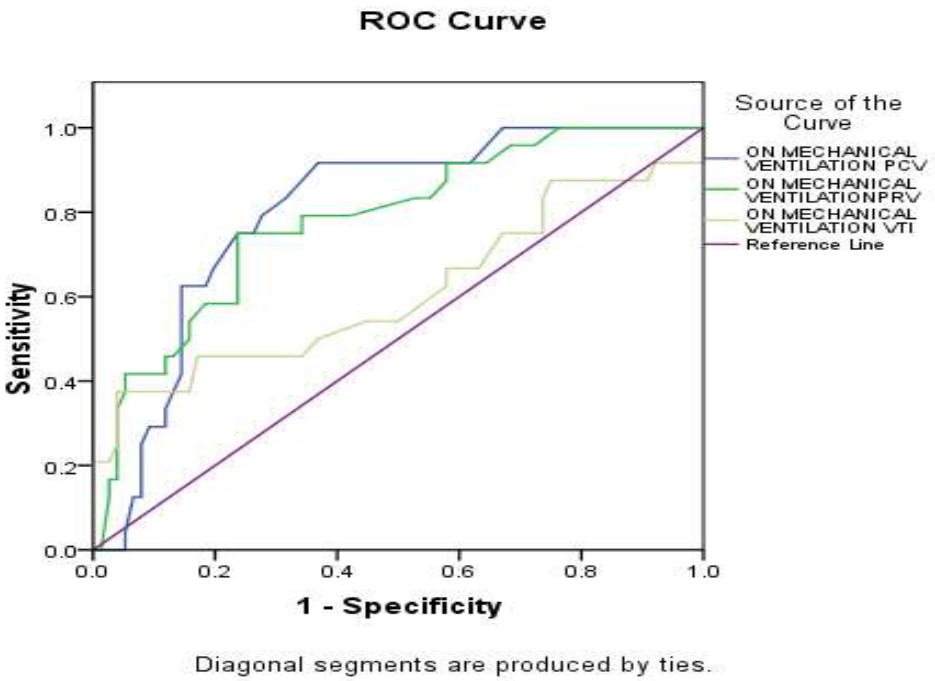

FIGURE 22. ROC CURVES OF TDI PARAMETERS: PCV, PRV, VTI FOR PREDICTION OF WEANING OUTCOMES.

TABLE 22. AREA UNDER THE CURVE (AUC) FOR ROC CURVES OF TDI PARAMETERS: PCV, PRV, VTI FOR PREDICTION OF WEANING OUTCOMES

Test Result Variable(s)	AUC	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
				Lower Bound	Upper Bound
ON MECHANICAL VENTILATION (PS/CPAP)PCV	0.802	0.046	0.000	0.711	0.892
ON MECHANICAL VENTILATION (PS/CPAP)PRV	0.781	0.053	0.000	0.678	0.885
ON MECHANICAL VENTILATION (PS/CPAP) VTI	0.611	0.076	0.102	0.463	0.759

PCV and PRV had a good correlation with prediction of weaning outcomes. VTI had a weak correlation for the same. PCV $\geq$2.45 had a 91.67% sensitivity and 63.16% specificity for weaning failure prediction. PRV $\geq$2.55 was 75% sensitive and 76.32% specific for weaning failure prediction. VTI $\geq$2.34 was 37.5% sensitive and 96.05% specific for weaning failure prediction.

TABLE 23. CORRELATION BETWEEN PCV-DE AND PCV-DETI

Spearman's rho		ON MV (PS/CPAP) PCV (cm/s)
ON MV (PS/CPAP) DE (cm)	Correlation Coefficient	-0.218
	p-value	0.029
	N	100
ON MV (PS/CPAP) DETI(cmsec)	Correlation Coefficient	-0.243
	p-value	0.015
	N	100

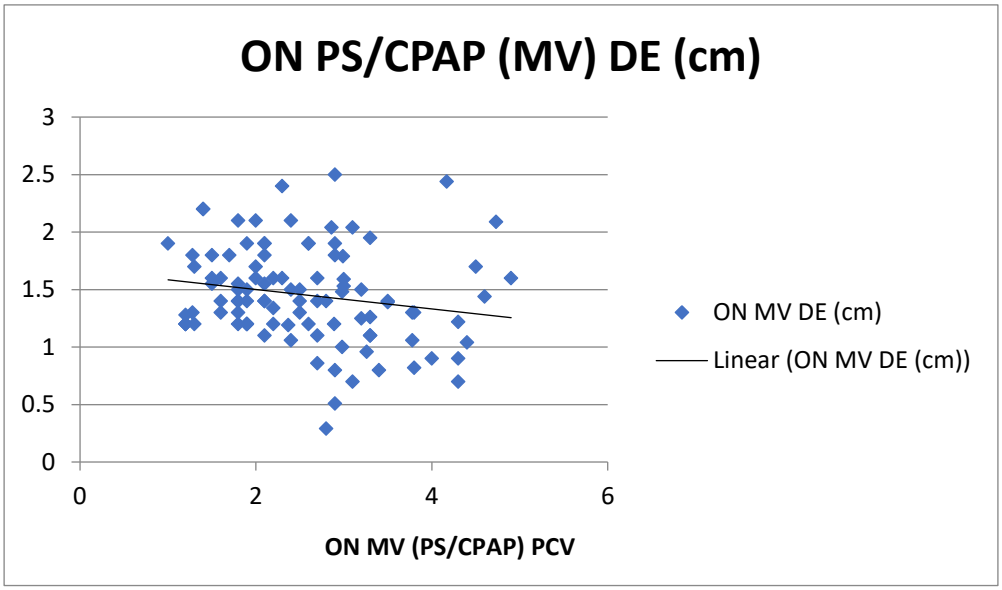

FIGURE 23. CORRELATION BETWEEN PCV AND DE ON PRESSURE-SUPPORT MODE OF VENTILATION

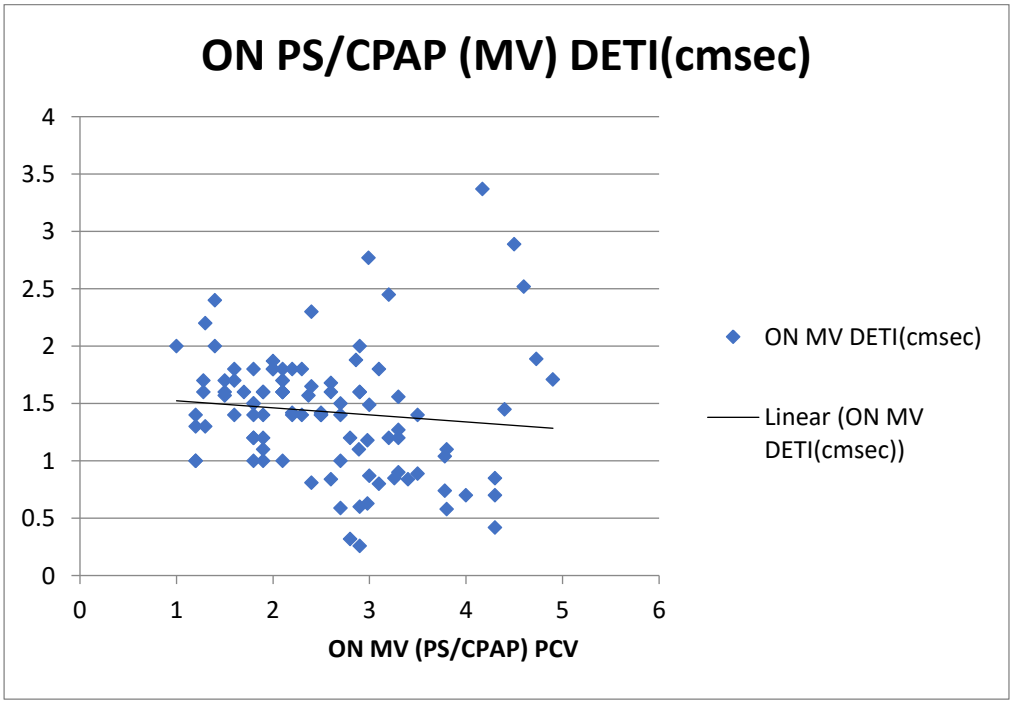

FIGURE 24. CORRELATION BETWEEN PCV AND DETI ON PRESSURE-SUPPORT MODE OF VENTILATION

There was found to be a statistically significant negative correlation between PCV vs DE (correlation coefficient=-0.218) and PCV vs DETI (correlation coefficient=-0.24) although the correlation was not very strong.

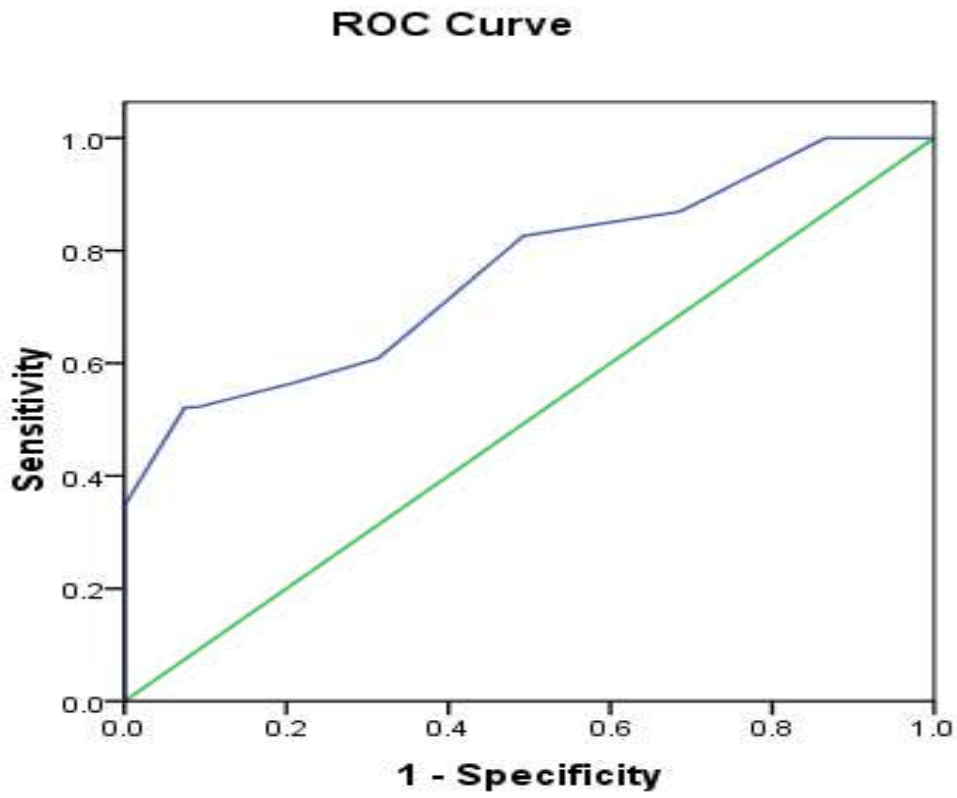

FIGURE 25. ROC CURVE FOR NIF FOR WEANING FAILURE PREDICTION

TABLE 24. AREA UNDER THE CURVE FOR NIF FOR WEANING FAILURE PREDICTION

Test Result Variable(s)	Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	-
-	-	-	-	Lower Bound	Upper Bound
NIF	.761	.063	.000	.639	.884

The ROC curve for NIF shows a good correlation (AUC=0.761) for prediction of weaning failure. NIF $\geq$ -20.5 was found to be 52.2% sensitive and 92.5 % specific for weaning failure prediction.

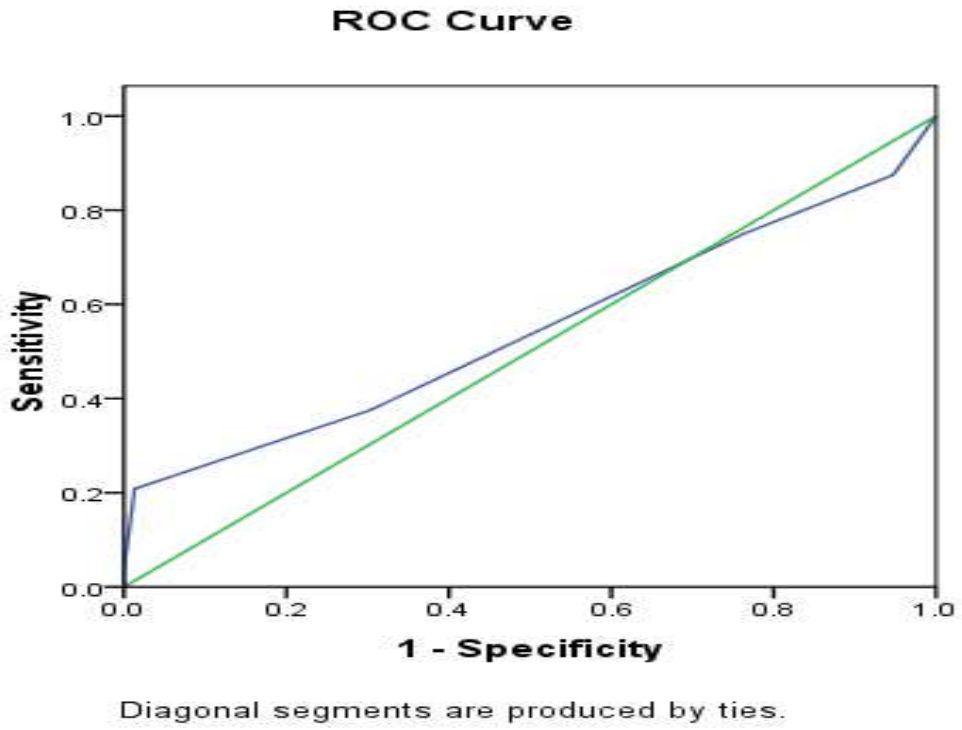

FIGURE 26. ROC CURVE FOR P0.1 FOR WEANING FAILURE PREDICTION

TABLE 25. AREA UNDER THE CURVE FOR P0.1 FOR WEANING FAILURE PREDICTION

Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
.544	.076	.516	.396	.692

P0.1 shows a poor correlation (AUC 0.544) for weaning failure prediction.

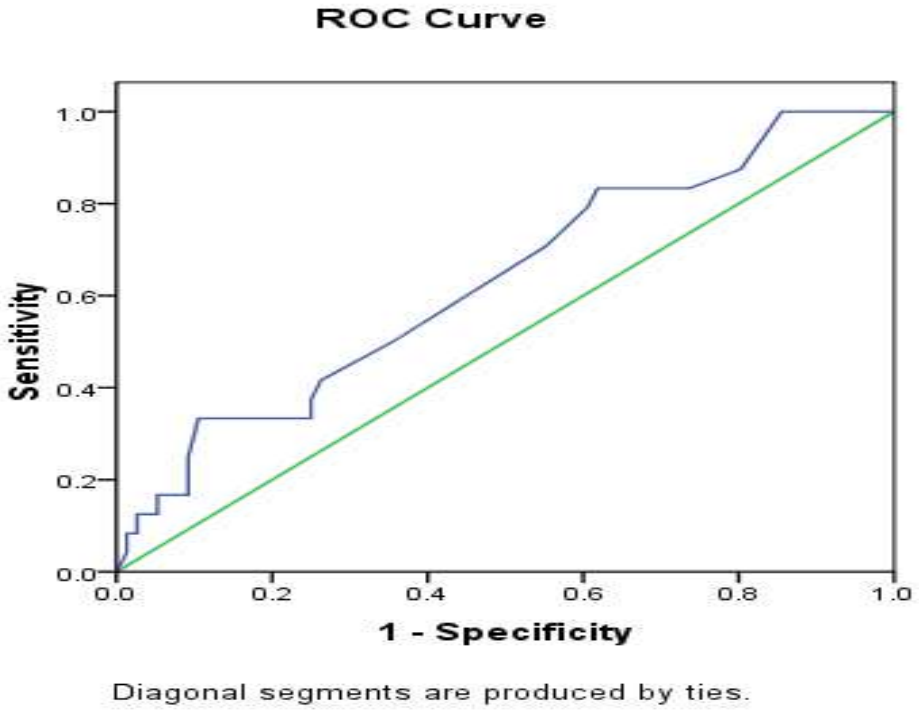

FIGURE 27. ROC CURVE FOR RSBI FOR WEANING FAILURE PREDICTION

TABLE 26. AREA UNDER THE CURVE FOR RSBI FOR WEANING FAILURE PREDICTION

Test Result Variable(s)	Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
				Lower Bound	Upper Bound
RSBI	.629	.065	.057	.502	.756

RSBI shows a weak correlation with prediction of weaning outcomes (AUC=0.629). RSBI≥40.5 shows an 83.33% sensitivity and 38.16% specificity, for weaning failure prediction.

DISCUSSION

The diaphragm is the major respiratory muscle; diaphragmatic dysfunction is responsible for difficult weaning from MV (Mechanical Ventilation) and prolonged MV may promote diaphragmatic dysfunction named as VIDD (Ventilator Induced Diaphragmatic Dysfunction). MV for even 6–12 hours can result in significant diaphragmatic atrophy or diaphragmatic dysfunction, as shown in animal studies. Therefore, diaphragmatic dysfunction can significantly interact with MV, and it is time-dependent in a linear manner [34].

Monitoring diaphragm function in the ICU could help physicians to more clearly understand the interaction between the patient's effort and the ventilator. It could participate in the ventilator setting and decision-making process. Ultimately, diaphragm function monitoring could be very useful in patients with difficult and prolonged weaning by predicting weaning failure and diagnosing diaphragm dysfunction.[31]

Thus, we in our present study aimed to assess the role of diaphragm parameters, diaphragm excursion (DE), diaphragm thickness fraction(DTF), diaphragm excursion-time index (DETI) and Tissue Doppler Imaging (TDI) during weaning from mechanical ventilation.

This was a prospective observational study conducted in patients admitted to intensive care units of our hospital during a period of 12 months (January 2022 to December 2022), who were recovering from their illness and were ready to be weaned from MV. A total number of 124 patients were screened, out of whom, 4 refused consent and 20 met exclusion criteria, hence, diaphragmatic parameters were assessed in 100 patients, at 3 points of time, on PS ventilation, 30 minutes after T piece trial and 24 hrs after extubation, using ultrasound, as previously mentioned and were divided into 2 groups based on weaning success (76 patients) or failure (24 patients), for the purpose of statistical analysis.

The mean age was significantly higher (p=0.015) in weaning failure group (52.45±13.55 years) versus (44.32±14.07 years) in weaning success group. However, previous studies on weaning have reported

comparable age between the weaning success and failure groups. [9,10,37]. Also on age-stratification of our patients for age less than or more than 50 years, the difference between success and failure groups was found to be statistically significant (p=0.032). The probable reason for this finding in our study could be that age-related changes limit the respiratory reserve, which affects the body's ability to provide adequate oxygen supply when demand increases. Thus during weaning there may be an imbalance between supply and demand resulting in weaning failure. [47]The patients, who failed the weaning trial, had a longer duration of mechanical ventilation 10.04±3.95 days versus those who succeeded the trial 4.91±2.61 days. This finding was in concordance with the study conducted by Ferrari et al [29]. The longer duration of mechanical ventilation may lead to ventilator induced diaphragmatic dysfunction resulting in ventilator dependence and weaning failure. The SOFA score was significantly (p=0.001) higher in weaning failure group (6.75±1.80) compared to the success group (5.00±2.17). The MRC grading of muscle power was lower, 4.36±0.73 in failure group compared to 4.76±0.46 in success group (p=0.007). The MRC grading could not be performed for total 10 patients due to low GCS or lack of co-operation. The NIF was also higher, -24.45±2.34 in the success group compared to -20.7±4.34 in the failure group (p=0.001). This was also reported by Pirompanich and Romsaiyut in their study [37]. BNP was also higher amongst the patients who failed the weaning trial, in our study. The mean BNP values were 152.92+/-223.71 in the weaning failure group and 62.26+/-20.99 in the weaning success group (p=0.027). These findings are in concordance with the study by Mekontso-Dessap et al., who reported the outcome of two weaning strategies, one was driven by BNP level, whereas the other followed no explicit protocol. They concluded that the BNP-guided fluid strategy was associated with increased use of diuretics, more negative fluid balance leading to a shorter mechanical ventilation time, and more ventilator-free days. [26]

Both the groups in our study were comparable in terms of the other baseline characteristics such as BMI, sex, GCS, RSBI, P0.1, total

leukocyte count, hemoglobin , S. albumin, Left Ventricular Ejection-Fraction (LVEF), S. calcium, potassium and phosphorus. There was a statistically significant difference between the 2 groups in terms of BNP and not in terms of LVEF. This can very well be explained by the fact that impaired systolic function (i.e., a small left ventricular ejection fraction [LVEF]) is associated only in 33% of patients who fail the SBT while 67% have left ventricular diastolic dysfunction [18]. The study by Palkar et al [35], reports a significant difference between weaning success and failure groups in terms of RSBI. In our study, RSBI was 48.63±12.84 breaths/min/litre in the failure group whereas, 42.39±11.86 breaths/min/litre in the success group (p=0.057). This contrast could have been because in our study, we calculated RSBI on PS/CPAP mode with a Pressure Support varying between 5-10cm water, while Palkar et al, had calculated RSBI on PS of 5 cm of water for all patients. This difference in methodology could have resulted in relatively lower RSBI values in our study.

Among all baseline characteristics that were statistically significant on univariate analysis, namely, age, days on mechanical ventilation, SOFA score, MRC grading of muscle power, NIF and BNP, a multivariate regression analysis was done. This showed that longer duration of mechanical ventilation had 1.6 times higher odds of weaning failure (OR 1.567, p=0.001) and lower NIF had 1.48 times higher odds of weaning failure (OR= 1.478, p=0.014), while age, SOFA score, muscle power and BNP were statistically insignificant .

Delirium assessment was done using the CAM-ICU tool. It could not be performed on 16 patients due to lack of co-operation or low GCS. The incidence of delirium was found to be significantly higher(p=0.015) in the weaning failure group (58.3%) as compared to the success group (23.7%) . Also, a greater proportion of patients in the weaning failure group had co-morbidities (37.5%) as compared to the success group (15.8%), p value=0.013 i.e. the difference was statistically significant. The presence or absence of co-morbidities namely, CKD (Chronic Kidney Disease), CLD (Chronic Liver Disease), hypothyroidism, COPD (Chronic Obstructive Pulmonary Disease), heart failure, Diabetes

Mellitus (DM), HTN (Hypertension) and moderate to gross pleural effusion were recorded for each patient. The major co-morbidity reported in our study was DM, 20.8% in the failure group vs 6.6% in the success group. However, in the study done by Palkar et al[9], there was no statistically significant difference in the incidence of co-morbidities between the 2 groups. The co-morbidities that they had compared in their study were asthma/COPD, DM, hypertension, heart failure and renal failure.

In our study, all the patients were given a trial of PSV(Pressure Support Ventilation), varying from 5-10cm of water, and if well-tolerated for minimum 30 minutes, the lung mechanics parameters, RSBI(Rapid Shallow Breathing Index), NIF(Negative Inspiratory Force), P0.1(Airway Occlusion Pressure) were measured and recorded, to be later compared with diaphragmatic parameters namely, DE, Inspiratory time(Ti), DETI, DTF, TDI parameters including PCV, PRV and VTI.

Patients were given a T-piece trial if they meet the following criteria: adequate oxygenation (oxygen saturation as measured by pulse oximetry at least 92%, $FiO_2 \leq 40\%$, P/F ratio >200, PEEP requirement $\leq$5cm water,), hemodynamic stability with minimal vasopressor or inotropic support, and normal metabolic status, respiratory rate <30/min, appropriate mental status and cooperation, relatively less secretions and improving chest imaging. The above mentioned diaphragmatic parameters were again measured by ultrasound examination in the ICU patients at the end of a 30-minute T-piece weaning trial. The measurements at this point of time, could not be taken on 3 patients who failed the T piece trial even before completion of 30 minutes and had to be put back on controlled mechanical ventilation. Reinstitution of mechanical ventilation was initiated if signs of respiratory distress, diaphoresis, tachypnea, hypoxemia and/or hypercapnia, hemodynamic instability or altered sensorium were observed. Weaning success was considered if ventilatory support, including non-invasive ventilation, was not required for 48 hours after extubation.

So, each of the above mentioned diaphragm ultrasound parameters were measured on Pressure- support ventilation, after 30 minutes of T-piece trial and after 24 hrs of extubation. To mitigate interobserver variability, a single intensivist was involved in taking measurements of all the patients. The average of three readings was taken to mitigate the effect of intra-observer variability. The investigator was not involved in the actual treatment or weaning of the patient and the treating team of the patient was blinded to ultrasound measurements.

In our study, the mean DE on PS/CPAP mode of MV was 1.02±0.35 cm in the failure group versus 1.59±0.34cm in the success group and the difference was statistically significant (p=0.001). Similarly, in the study done by Palkar et al [9] DE measured on PS/CPAP mode of ventilation, was 1.65±0.82cm in failure group vs 2.1±0.9 cm in success group (p=0.06). In our study, the Ti on PS/CPAP mode was statistically lower (p=0.008) in failure group, 0.90±0.30 s as compared to the success group 1.00±0.21 s. This is in concordance with their study where, Ti in failure group was 0.89±0.30 s versus 1.11±0.39 s in success group (p=0.03). In our study, the mean value of DETI on PS/CPAP mode, in failure group was 0.94±0.49 cm s vs 1.58±0.46 cm s in success group (p=0.001). The mean DETI reported by Palkar et al[35] in their study, on PS/CPAP mode was 1.64±1.19 cm s vs 2.42±1.55 cm s in the failure and success groups respectively(p<0.03). In our study, mean DTF in failure group was 22.93±18.09% versus 43.14± 24.06% in success group (p=0.001). These findings are in concordance with the study done by Pirompanich and Romsaiyut [37] ; p<0.001).

The TDI parameters of diaphragm as measured in our study, on PS/CPAP mode of MV were PCV, PRV and VTI. There was a statistically significant difference between median PCV in failure group 3.20 (2.83-3.80) cm/s versus 2.10 (1.80-2.88) cm/s in success group (p=0.001). The median PRV was 2.90 (2.44-3.88) in failure group versus 2.20(1.70-2.50)cm/s (p=0.001) in success group. The mean VTI was 1.45 (0.95-2.48) cm/s in failure group vs 1.23(0.89-1.73)cm/s

in success group (p=0.102). To the best of our knowledge, there is only one previous study on TDI of diaphragm in adults by Soilemezi et al [10] who have compared TDI diaphragm values on patients on T piece weaning trial, amongst weaning failure and success patients. Our study's findings are in concordance with their study's findings. We analysed them as both mean and median values for comparison and found them to be comparable. The difference between PCV and PRV between the two groups as reported in their study was statistically significant (p=0.001 and p<0.001 respectively). The p value for comparison of VTI between the 2 groups was 0.178 in their study.

There is scarce data in literature concerning the diaphragmatic TDI pattern and range of normal values in healthy individuals or in ICU patients. One of the probable reasons for the high contraction velocities observed in our study in the weaning failure patients is related to the fact that most weaning failure patients also develop an increase in respiratory motor output as they experience progressive ventilatory failure [10]. The resulting increase in minute ventilation can be achieved either through an increase in rate or depth of breathing, but whether an increase in diaphragmatic motion velocity constitutes part of this respiratory response is not known because diaphragmatic velocity has undergone limited investigation to date.

After evaluation of all the parameters on PS/CPAP mode of ventilation, the measurements of all parameters were performed after 30 minutes of T piece trial and findings were similar and comparable at this point of time also. A repeat evaluation was conducted after 24 hrs for all patients who were on spontaneous ventilation. At this point of time, we could evaluate all patients in weaning success group (76 patients) but however, measurements for only 1 patient out of 24 in the failure group could be evaluated because rest of all had been put back on controlled mode of ventilation. In this study, we have assessed our patients during spontaneous breathing only because TDI assesses only the absolute tissue velocity and is unable to discriminate passive from active motion. Also , the DE, Ti and DETI cannot distinguish between active and passive motion and as our aim was to determine

the efficacy of diaphragmatic parameters for predicting weaning outcomes, we compared the parameters on spontaneous breathing only.

In our study, ROC curve for DETI showed AUC 0.864 for weaning success prediction and a DETI ≥ 1.32 cm had a sensitivity and specificity of 75% and 91.7% respectively. This was in contrast to the study done by Palkar et al [9], where the AUC for DETI was 0.66. This difference can be explained by the fact these readings were taken on A/C mode in their study and on PS/CPAP mode in our study. Hence a higher AUC value on PS/CPAP shows the better reliability of this index on spontaneous breathing for predicting weaning outcomes.

In our study, the ROC curve for DTF showed AUC 0.869, for weaning success prediction with DTF≥24.5% being 89.5% sensitive and 75% specific. This was in concordance with the study done by Pirompanich and Romsaiyut [37] where the AUC for right DTF was 0.951. In our study, we have also taken all measurements from the right hemidiaphragm only as visaulisation of the diaphragm through this window is easier and also to maintain uniformity.

We have also done ROC curve analysis for the TDI parameters in order to obtain cut-off values for weaning failure prediction. For PCV, the AUC was 0.802, and PCV≥2.45 had a 91.67% sensitivity and 63.16% specificity for weaning failure prediction. For PRV, the AUC was 0.781 and PRV≥2.55 was 75% sensitive and 76.32% specific for weaning failure prediction. Whereas, for VTI, the AUC was 0.611 and VTI≥2.34 was found to be 37.5% sensitive and 96.05% specific for weaning failure prediction.

Soilemezi and colleagues[10] applied cardiac TDI methods to study the diaphragm. Despite an overlap in values for inspiratory velocity, patients who failed weaning trials had significantly higher peak dome velocities than patients who were successfully weaned from the ventilator. This has been found in our study also.

We have also attempted to find out if any correlation exists between PCV vs DE and DETI, in our study. There was a significant negative correlation between PCV versus DE (correlation coefficient =-0.218,

p=0.029), and between PCV versus DETI (correlation coefficient = -0.243, p=0.015), although this correlation was not very strong.

LIMITATIONS

Despite all the effective measures taken, there are a few limitations in this study:

1. This was a single centre study.
2. 3 patients who failed the weaning trial and were put back on controlled mode of ventilation before completion of the 30 minutes could not be analysed for diaphragm assessment at 30 minutes.
3. Similarly, those patients who failed the weaning trial before completion of the 24 hour period and were put back on controlled mode of ventilation, they could not be analysed for diaphragm assessment, as it had to be done only on spontaneously breathing patients.
4. Confounding factors such as cardiac failure, pulmonary infections, obstructive airway disease, reduced respiratory drive, etc were not identified in this study that could have influenced the results.
5. There can be a wide inter as well as intra-observer variation in the diaphragm ultrasound measurements, however in our study, the measurements were noted by only one observer and a mean of 3 measurements were taken into consideration.
6. We performed TDI measurements on the right hemidiaphragm because it is technically easier. Additionally, in some patients with large diaphragmatic displacement, contamination of the TDI sample volume with liver tissue may be observed. However, it has been demonstrated that adjacent tissues move similarly with the diaphragm during quiet and deep breathing.

SUMMARY

We conducted an institutional and prospective study in a tertiary care hospital for a duration of 12 months from January 2022 to December 2022. We enrolled 100 patients who had been on invasive mechanical ventilation for more than 24 hours when they were being planned for weaning. We recorded the baseline characteristics and lung mechanics of all those patients when they were being weaned off and were taken on pressure-support mode of ventilation (PS=5-10cm water) and performed diaphragm ultrasound on them which was repeated after 30 minutes and 24 hours. All patients were followed up for 48 hours and were divided into 2 groups based on weaning success and failure. 76 patients succeeded while 24 patients failed the weaning trial.

SALIENT FINDINGS:

1. Diaphragm excursion, excursion time index, thickness- fraction and TDI parameters PCV and PRV can strongly predict weaning outcomes.
2. They all are even better predictors of weaning outcomes than RSBI (Rapid Shallow Breathing Index), NIF (Negative Inspiratory Force) and P0.1 (Occlusion Pressure) as shown by their ROC curves.
3. PCV and PRV are good predictors of weaning outcomes with PCV $\geq$2.45 had a 91.67% sensitivity and 63.16% specificity for weaning failure prediction. PRV $\geq$2.55 was 75% sensitive and 76.32% specific for weaning failure prediction. VTI $\geq$2.34, being 37.5% sensitive and 96.05% specific for weaning failure prediction, had a weak correlation with weaning failure prediction.
4. In this study, there was a statistically significant negative correlation between PCV vs DE and PCV vs DETI, although the correlation was not very strong.

CONCLUSION:

The diaphragmatic excursion time index is a novel method that may aid in predicting weaning and extubation outcomes. A higher diaphragmatic excursion, excursion- time index and thickness fraction during SBT are predictive of successful weaning . TDI of diaphragm is

a new sonographic approach that allows real-time assessment of the velocity of diaphragmatic motion. In this study, PCV and PRV of diaphragm, obtained through TDI have been found to be good predictors of weaning outcomes. Further large prospective studies are needed to validate these findings.

BIBLIOGRAPHY

1. Mahmoodpoor A, Fouladi S, Ramouz A, Shadvar K, Ostadi Z, Soleimanpour H. Diaphragm ultrasound to predict weaning outcome: systematic review and meta-analysis. Anaesthesiol Intensive Ther. 2022;54:164-74.
2. Krieger BP, Ershowsky PF, Becker DA, Gazeroglu HB. Evaluation of conventional criteria for predicting successful weaning from mechanical ventilatory support in elderly patients. Crit Care Med. 1989;17:858-61.
3. Laghi F, Cattapan SE, Jubran A, Parthasarathy S, Warshawsky P, Choi YS, et al. Is weaning failure caused by low-frequency fatigue of the diaphragm? Am J Respir Crit Care Med. 2003;167:120-7.
4. Vassilakopoulos T, Petrof BJ. A Stimulating Approach to Ventilator-induced Diaphragmatic Dysfunction. Am J Respir Crit Care Med. 2017;195:281-2.
5. Macintyre NR. Evidence-based assessments in the ventilator discontinuation process. Respir Care. 2012;57:1611-8.
6. Thille AW, Cortés-Puch I, Esteban A. Weaning from the ventilator and extubation in ICU. Curr Opin Crit Care. 2013;19:57–64.
7. Béduneau G, Pham T, Schortgen F, Piquilloud L, Zogheib E, Jonas M, et al; WIND (Weaning according to a New Definition) Study Group and the REVA (Réseau Européen de Recherche en Ventilation Artificielle) Network ‡. Epidemiology of Weaning Outcome according to a New Definition. The WIND Study. Am J Respir Crit Care Med. 2017;195:772-83.
8. Dres M, Dubé BP, Mayaux J, Delemazure J, Reuter D, Brochard L, et al. Coexistence and Impact of Limb Muscle and Diaphragm Weakness at Time of Liberation from Mechanical Ventilation in Medical Intensive Care Unit Patients. Am J Respir Crit Care Med. 2017;195:57-66.

9. Palkar A, Narasimhan M, Greenberg H, Singh K, Koenig S, Mayo P, et al. Diaphragm excursion-time index: a new parameter using ultrasonography to predict extubation outcome. Chest. 2018;153:1213-20.
10. Soilemezi E, Savvidou S, Sotiriou P, Smyrniotis D, Tsagourias M, Matamis D. Tissue Doppler imaging of the diaphragm in healthy subjects and critically ill patients. American Journal of Respiratory and Critical Care Medicine. 2020;202:1005-12.
11. Peñuelas O, Frutos-Vivar F, Fernández C, Anzueto A, Epstein SK, Apezteguía C, et al; Ventila Group. Characteristics and outcomes of ventilated patients according to time to liberation from mechanical ventilation. Am J Respir Crit Care Med. 2011;184:430-7.
12. Bruni A, Garofalo E, Pelaia C, Messina A, Cammarota G, Murabito P, et al. Patient-ventilator asynchrony in adult critically ill patients. Minerva Anestesiol. 2019;85:676-88.
13. Lemaire F, Teboul JL, Cinotti L, Giotto G, Abrouk F, Steg G, et al. Acute left ventricular dysfunction during unsuccessful weaning from mechanical ventilation. Anesthesiology. 1988;69:171-9.
14. Esteban A, Alía I, Gordo F, Fernández R, Solsona JF, Vallverdú I, Macías S, et al. Extubation outcome after spontaneous breathing trials with T-tube or pressure support ventilation. The Spanish Lung Failure Collaborative Group. Am J Respir Crit Care Med. 1997;156:459-65.
15. Frutos-Vivar F, Ferguson ND, Esteban A, Epstein SK, Arabi Y, Apezteguía C, et al. Risk factors for extubation failure in patients following a successful spontaneous breathing trial. Chest. 2006;130:1664-71.
16. Meade M, Guyatt G, Cook D, Griffith L, Sinuff T, Kergl C,et al.Predicting success inweaning from mechanical ventilation. Chest 120:400S–24S

17. Thille AW, Richard JC, Brochard L. The decision to extubate in the intensive care unit. Am J Respir Crit Care Med. 2013;187:1294-302.
18. Vetrugno L, Guadagnin GM, Brussa A, Orso D, Garofalo E, Bruni A, et al. Mechanical ventilation weaning issues can be counted on the fingers of just one hand: part 1. Ultrasound J. 2020;12:9.
19. Namen AM, Ely EW, Tatter SB, Case LD, Lucia MA, Smith A, Landry S, et al. Predictors of successful extubation in neurosurgical patients. Am J Respir Crit Care Med. 2001;163:658-64.
20. Moschietto S, Doyen D, Grech L, Dellamonica J, Hyvernat H, Bernardin G. Transthoracic Echocardiography with Doppler Tissue Imaging predicts weaning failure from mechanical ventilation: evolution of the left ventricle relaxation rate during a spontaneous breathing trial is the key factor in weaning outcome. Crit Care. 2012;16:R81.
21. Burns KEA, Soliman I, Adhikari NKJ, Zwein A, Wong JTY, Gomez-Builes
C,et al.Trials directly comparing alternative spontaneous breathing trial techniques: a systematic review and meta-analysis. Crit Care 21:127
22. Malbrain MLNG, Van Regenmortel N, Saugel B, De Tavernier B, Van Gaal PJ, Joannes-Boyau O, et al. Principles of fluid management and stewardship in septic shock: it is time to consider the four D's and the four phases of fluid therapy. Ann Intensive Care. 2018;8:66.
23. Boyd JH, Forbes J, Nakada TA, Walley KR, Russell JA. Fluid resuscitation in septic shock: a positive fluid balance and elevated central venous pressure are associated with increased mortality. Crit Care Med. 2011;39:259-65.
24. Pandey A, Khera R, Kumar N, Golwala H, Girotra S, Fonarow GC. Use of Pulmonary Artery Catheterization in US Patients

With Heart Failure, 2001-2012. JAMA Intern Med. 2016;176:129-32.

25. Ferré A, Guillot M, Lichtenstein D, Mezière G, Richard C, Teboul JL, Monnet X. Lung ultrasound allows the diagnosis of weaning-induced pulmonary oedema. Intensive Care Med. 2019;45:601-8.
26. Mekontso Dessap A, Roche-Campo F, Kouatchet A, Tomicic V, Beduneau G, Sonneville R, et al.Natriuretic pep- tide-driven fluid management during ventilator weaning: a randomized controlled trial. Am J Respir Crit Care Med 186:1256–63.
27. Monod H, Scherrer J. The work capacity of a synergic muscular group. Ergonomics 8:329–38
28. Macklem PT, Roussos CS. Respiratory muscle fatigue: a cause of respiratory failure?. Clinical science and molecular medicine. 1977 ;53:419-22.
29. Ferrari G, De Filippi G, Elia F, Panero F, Volpicelli G, Aprà F. Diaphragm ultrasound as a new index of discontinuation from mechanical ventilation. Critical ultrasound journal. 2014;6:1-6.
30. Levine S, Nguyen T, Taylor N, Friscia ME, Budak MT, Rothenberg P, et al. Rapid disuse atrophy of diaphragm fibers in mechanically ventilated humans. N Engl J Med. 2008;358:1327-35.
31. Dres M, Demoule A. Monitoring diaphragm function in the ICU. Curr Opin Crit Care. 2020;26:18-25.
32. Dres M, Goligher EC, Heunks LMA, Brochard LJ. Critical illness-associated diaphragm weakness. Intensive Care Med. 2017;43:1441-52.
33. American Thoracic Society/European Respiratory Society. ATS/ERS Statement on respiratory muscle testing. Am J Respir Crit Care Med. 2002;166:518-624.
34. Zhang X, Yuan J, Zhan Y, Wu J, Liu B, Zhang P,et al. Evaluation of diaphragm ultrasound in predicting extubation outcome in mechanically ventilated patients with COPD. Ir J Med Sci. 2020;189:661-8.

35. Grasselli G, Zangrillo A, Zanella A, Antonelli M, Cabrini L, Castelli A, et al. Baseline characteristics and outcomes of 1591 patients infected with SARS-CoV-2 admitted to ICUs of the Lombardy Region, Italy. Jama. 2020;323:1574-81.
36. Vetrugno L, Orso D, Corradi F, Zani G, Spadaro S, Meroi F, et al. Diaphragm ultrasound evaluation during weaning from mechanical ventilation in COVID-19 patients: a pragmatic, cross-section, multicenter study. Respir Res. 2022;23:210.
37. Pirompanich P, Romsaiyut S. Use of diaphragm thickening fraction combined with rapid shallow breathing index for predicting success of weaning from mechanical ventilator in medical patients. J Intensive Care. 2018;6:6.
38. Saravanan R, Nivedita K, Karthik K, Venkatraman R. Role of diaphragm ultrasound in weaning mechanically ventilated patients: A prospective observational study. Indian J Anaesth. 2022;66:591-8.
39. Li C, Li X, Han H, Cui H, Wang G, Wang Z. Diaphragmatic ultrasonography for predicting ventilator weaning: A meta-analysis. Medicine (Baltimore). 2018;97:e10968.
40. Gok F, Mercan A, Kilicaslan A, Sarkilar G, Yosunkaya A. Diaphragm and Lung Ultrasonography During Weaning From Mechanical Ventilation in Critically Ill Patients. Cureus. 2021;13:e15057.
41. DiNino E, Gartman EJ, Sethi JM, McCool FD. Diaphragm ultrasound as a predictor of successful extubation from mechanical ventilation. Thorax. 2014;69:431-5.
42. Ho CY, Solomon SD. A clinician's guide to tissue Doppler imaging. Circulation. 2006;113:e396-8.
43. Abraham TP, Dimaano VL, Liang HY. Role of tissue Doppler and strain echocardiography in current clinical practice. Circulation. 2007;116:2597-609.
44. McCool FD, Tzelepis GE. Tissue Doppler imaging of the diaphragm: a new kid on the block?. American Journal of Respiratory and Critical Care Medicine. 2020 Oct 1;202:921-2.

45. McCool FD, Tzelepis GE, Leith DE, Hoppin FG Jr. Oxygen cost of breathing during fatiguing inspiratory resistive loads. J Appl Physiol (1985). 1989;66:2045-55.
46. Mekontso Dessap A, Roche-Campo F, Kouatchet A, Tomicic V, Beduneau G, Sonneville R, et al. Natriuretic peptide-driven fluid management during ventilator weaning: a randomized controlled trial. Am J Respir Crit Care Med. 2012;186:1256-63.
47. Thompson LF. Failure to wean: exploring the influence of age-related pulmonary changes. Crit Care Nurs Clin North Am. 1996;8:7-16.

S. NO	MRD	AGE (years)	AGE GROUP	SEX	BMI	BMI GROUP	DAYS ON MV	REASON FOR ICU ADMSSN	CO MORBIDITIES	SOFA	GCS	MRC MUSCLE POWER	RSBI
1	1203117	35	2	M	34	4	2	Septic shock S/P laprotomy for perforation peritonitis	-	3	11	5	40
2	1202116	31	2	M	21.5	1	8	Founiers gangrene post debridement	-	4	11	5	45
3	1195899	23	1	M	22.8	2	2	S/P lap for Perforation peritonitis	-	3	11	5	40
4	1202572	34	2	M	32	4	6	S/P lap for Perforation peritonitis	-	3	11	5	46
5	1200128	25	1	F	24	2	2	S/P LSCS IUD Eclampsia	Heart failure	6	11	5	40
6	1300804	20	1	M	26	3	4	S/P ORIF for maxillofacial injury and Left eye globe injury	-	2	11	5	50
7	1200156	28	1	M	23	2	5	OPC poisoning	-	2	11	5	78
8	1199754	28	1	M	27.6	3	11	Acute pancreatitis S/P Necrosectomy with CO2 retention	-	2	11	5	60
9	1199714	24	1	F	23.7	2	2	S/P Perforation peritonitis	-	2	11	5	29
10	1200286	50	3	F	23	2	8	Multiple rib fractures with flail chest with hemopneumothorax	-	7	11	5	32
11	1401470	19	1	M	18.4	0	2	S/P Nasopharyngeal angiofibroma excision	-	2	11	4	38
12	1400776	57	4	F	22	1	6	UTI with pulmonary kochs with acute hepatitis	DM,HTN,CKD	7	11	5	62
13	375369	36	2	M	27	3	6	Septic shock S/P laprotomy for perforation peritonitis	-	4	11	5	35
14	1217650	37	2	F	24	2	6	S/P Perforation peritonitis	-	3	11	5	40
15	1221382	50	3	F	24.2	2	3	Septic shock with metabolic encephalopathy on peritoneal dialysis	-	7	10	3	14
16	1207617	57	4	F	25	3	6	Blunt trauma chest with multiple rib fractures and ICD in situ for hemopneumothorax	-	9	10	5	58
17	1186117	56	4	M	23	2	12	LRTI sepsis K/C/O Sarcoidosis	DM, HTN, COPD,R side gross pl effusion	6	11	5	44
18	1212603	62	5	M	25	3	14	Meckel's diverticulum S/P laprotomy in septic shock	Hypothyroidism	8	11	3	42
19	493101	67	5	F	21	1	3	Acute coronary syndrome	CKD	5	11	5	44
20	1213334	40	2	M	24.7	2	4	TBI (EDH) and Blunt trauma chest	-	3	8	-	41
21	1212014	45	3	F	24	2	5	S/P Sigmoid perforation repair	-	4	11	5	41
22	1202011	47	3	M	22.1	1	6	Upper GI bleed	-	6	9	-	50
23	1208649	63	5	F	23	2	3	DM,HTN,CLD,CKD	-	9	11	5	65
24	860837	65	5	M	37	4	3	S/P Lap for perforation peritonitis: Septic shock	DM,HTN	5	11	5	22
25	1208961	18	1	F	21	1	5	Polytrauma	-	3	11	5	38
26	1202632	28	1	F	24	2	5	TBI (SAH with contusions)	-	3	11	5	52
27	1207447	48	3	F	22	1	5	SDH with contusions	-	3	10	5	43
28	1205443	60	4	F	32.5	4	14	S/P duodenal perforation repair	CLD, Hypothyroidism	3	11	5	58
29	1107364	36	2	M	18	0	3	S/P hemicolectomy for cecal volvulus	-	2	11	5	45
30	1205382	25	1	M	18	0	3	S/P esophagectomy for corrosive injury	-	4	11	5	54
31	1448506	40	2	F	20	1	4	TBI SDH with contusiosn	-	3	10	4	45
32	1445183	50	3	F	19	1	5	Scrub typhus complicated tropical fever	-	5	10	4	43
33	1445210	36	2	M	25	3	6	Acute liver failure (HAV reactive)	-	7	11	5	42
34	1440358	48	3	F	23	2	6	TBI SDH with contusions	DM	5	8	-	40
35	1429305	72	6	M	34	4	10	Polytrauma	DM,HTN	6	11	5	43
36	365902	65	5	F	27	3	10	Biliary pancreatitis	-	7	11	4	66
37	349317	72	6	M	25	3	4	S/ P sigmoid perforation repair	HTN	8	11	4	45
38	458582	32	2	F	23	2	5	PPH post hysterectomy	-	7	11	5	34
39	144297	44	3	M	26	3	8	Polytrauma	hypothyroidism	6	11	4	67
40	1444595	56	4	F	25	3	4	S/P perforation peritonitis repair	-	4	11	5	54

S. NO	MRD	LUNG MECHANICS P0.1	NIF	TLC	HB	ALBUMIN	EF(%)	BNP	CALCIUM	POTASSIUM	PHOSPHORUS	CAM ICU	ON MECHANICAL VENTILATION DE (cm)	ON MV INSPIRATORY TIME(Ti) sec	ON MECHANICAL VENTILATION DETI(cmsec)	ON MECHANICAL VENTILATION DTF(%)	ON MECHANICAL VENTILATION PCV	ON MECHANICAL VENTILATION PRV
1	1203117	4	-26	12.2	11.8	3	60	52	8.2	5.5	7	neg	1.06	0.764150943	0.81	50	2.4	2.3
2	1202116	3	-25	12	12	3.4	60	60	8.5	4	3	neg	1.6	1.06875	1.71	62	4.9	3.5
3	1195899	3	-22	11.3	13.7	3.9	60	40	8.9	5	3	neg	1.53	0.568627451	0.87	60	3	2.7
4	1202572	3	-24	11	12	3.5	55	45	8.8	4.5	4	neg	0.29	1.103448276	0.32	18	2.8	1.95
5	1200128	3	-24	21.5	12.5	2.2	60	40	8.9	4.4	4	neg	2.44	1.381147541	3.37	30.7	4.17	2.73
6	1300804	3	-30	6.9	8.4	3.3	60	30	8.8	3.3	3.7	neg	1.22	0.696721311	0.85	25	4.3	3.13
7	1200156	1	-25	7	12.2	3.3	40	69	8.8	3.6	4	neg	1.44	1.75	2.52	78	4.6	3.26
8	1199754	2	-23	20.6	9	2.72	60	58	9	3.8	3	neg	1.3	0.8	1.04	25	3.78	4.5
9	1199714	2	-23	10.7	6	3.2	60	60	8.8	4.8	3.6	neg	1.4	1	1.4	60	3.5	6.4
10	1200286	1	-18	7.6	8.2	3.5	60	48	8.8	3.72	3.4	neg	0.82	0.707317073	0.58	23.8	3.8	3.9
11	1401470	3	-23	12	10.5	3	60	67	8.9	3.91	3.5	neg	2.09	0.90430622	1.89	27	4.73	2.48
12	1400776	3	-14	11.1	9.5	2.17	60	45	8.7	3.67	3.4	neg	0.86	0.686046512	0.59	19	2.7	1.8
13	375369	3	-22	11.7	11	2.6	60	65	8.7	3.8	3.4	neg	1.59	0.937106918	1.49	58	3	2.8
14	1217650	3	-24	12	10	3.4	60	57	8.9	4	3.8	neg	1.48	0.797297297	1.18	23.3	2.98	2
15	1221382	2	-28	20.9	8	3.3	60	56	10.5	3.06	3.4	-	1.79	1.547486034	2.77	190	2.99	2.4
16	1207617	3	-11	13.3	9.3	1.93	60	67	8.7	4.2	8.7	-	1	0.63	0.63	18.6	2.98	2.89
17	1186117	1	-26	9.7	9.6	1.69	40	775	7.3	5.02	2.08	neg	1.25	1.96	2.45	37	3.2	2.9
18	1212603	4	-20	11	9	1.9	60	60	8	4	3	pos	1.04	1.394230769	1.45	100	4.4	3.5
19	493101	3	-20	11	9	3	50	890	8	4.1	4	neg	1.2	0.7	0.84	21	2.6	2.39
20	1213334	2	-	9.4	11.2	4.6	60	50	8.7	2.9	3.8	-	1.06	0.698113208	0.74	17	3.78	3.65
21	1212014	3	-24	11	9	3	60	47	8.9	4.2	3.8	neg	1.34	1.059701493	1.42	30	2.2	2.3
22	1202011	4	-	5.1	7.9	3.62	40	102	8	3.67	3.6	-	1.7	1.7	2.89	20	4.5	4
23	1208649	4	-25	4	12.6	2.49	60	87	8.8	4.39	1.6	neg	1.5	1.1	1.65	56	2.4	1.9
24	860837	4	-20	11.4	16	3.9	60	79	8.8	4.8	3.27	neg	1.4	1.014285714	1.42	37	2.5	2.4
25	1208961	2	-25	13	10	2.9	60	45	8.9	4	4	neg	1.19	1.319327731	1.57	5.8	2.37	2.26
26	1202632	4	-26	12	10	3.2	60	67	9	3.7	2.9	neg	1.39	0.64028777	0.89	9	3.5	3.26
27	1207447	4	-	11	9	3.4	60	56	9.7	3.8	3.4	-	1.95	0.8	1.56	67	3.3	3.2
28	1205443	8	-26	6.3	8.9	2.3	60	57	8	3.45	4	neg	0.96	0.885416667	0.85	0	3.26	2.6
29	1107364	2	-26	8	9	2.73	60	56	8	3.8	3	neg	2.04	0.921568627	1.88	35	2.86	2.73
30	1205382	1	-22	8.6	9.6	4.39	60	66	7.8	3.13	2.3	neg	1.26	1.007936508	1.27	34	3.3	3.2
31	1448506	3	-24	8	9	3	60	56	7	3.7	2	-	1.6	1.0625	1.7	28	1.5	1.53
32	1445183	3	-26	14	8	2.3	44	45	8	3.6	3.7	-	1.7	1.1	1.87	36	2	2.2
33	1445210	3	-24	22	8.9	2	60	44	7.8	3.2	2.3	-	1.1	0.909090909	1	26	2.7	1.76
34	1440358	4	-	16	9.8	2.6	60	56	8.2	5.1	5.6	NA	1.8	0.888888889	1.6	38	1.7	1.74
35	1429305	3	-24	14	9.8	2.5	60	120	7.6	3.4	3.2	pos	0.8	1.05	0.84	18	3.4	4.5
36	365902	4	-19	14	8.8	2.6	60	88	7.6	5	4.5	pos	1.1	1.090909091	1.2	16	3.3	4.5
37	349317	1	-20	12	7.9	2	42	112	7	3.3	2	pos	1.4	1.285714286	1.8	36	2.1	1.78
38	458582	2	-25	14	7.9	2.1	60	60	7.2	3.5	3	neg	1.3	1.307692308	1.7	44	1.28	0.96
39	144297	3	-27	12	8.2	2.3	60	57	8	3.5	1.8	pos	1.4	0.857142857	1.2	56	1.8	1.6
40	1444595	3	-25	13	7.8	1.9	60	58	7	4.8	3.3	neg	1.7	1.294117647	2.2	76	1.3	1.1

S. NO	MRD	ON MECHANICAL VENTILATION VTI	30MINS OF WEANING TRIAL DE	30 MIN WEANING TRIAL Ti(sec)	30MINS OF WEANING TRIAL DETI	30MINS OF WEANING TRIAL DTF(%)	30MINS OF WEANING TRIAL PCV	30MINS OF WEANING TRIAL PRV	30MINS OF WEANING TRIAL VTI	24 HRS OF WEANING TRIAL DE	24 HRS WEANING Ti (sec)	24 HRS OF WEANING TRIAL DETI	24 HRS OF WEANING TRIAL DTF(%)	24 HRS OF WEANING TRIAL PCV	24 HRS OF WEANING TRIAL PRV	24 HRS OF WEANING TRIAL VTI	OUTCOME
1	1203117	2.3	1.06	0.5	0.53	65	2.4	2.3	2.3	1.08	0.74074074	0.8	70	2.4	2.3	2.5	SUCCESS
2	1202116	2.06	1.7	1.052941176	1.79	66	4.95	3.52	2.06	1.7	1.05294118	1.79	65	4.5	3.5	2.3	SUCCESS
3	1195899	2.5	1.53	0.568627451	0.87	60	3	2.4	2.2	1.77	1.06779661	1.89	70	4	3	1.8	SUCCESS
4	1202572	0.6	0.84	0.297619048	0.25	18	2.7	1.95	0.6	-	-	-	-	-	-	-	FAILURE
5	1200128	1.26	1.08	1.111111111	1.2	50	2.73	1.6	1.5	2.37	1.13924051	2.7	39	2.9	2	1.6	SUCCESS
6	1300804	1.04	1.33	0.759398496	1.01	48	4.3	3.14	2.02	1.5	0.94	1.41	30	3.78	3.39	3.78	SUCCESS
7	1200156	2	1.6	0.8	1.28	90	4.69	3.4	2.2	1.4	1.21428571	1.7	90	4.6	3.3	2.13	SUCCESS
8	1199754	0.8	1.4	1.2	1.68	25	3.78	4.69	0.8	1.4	1.2	1.68	40	3.78	4.5	0.79	SUCCESS
9	1199714	2	1.92	1.817708333	3.49	61.9	3.51	6.4	2	1.95	1.20512821	2.35	70	3.52	6.64	2.5	SUCCESS
10	1200286	0.47	1.26	0.587301587	0.74	48	3.8	4.34	0.51	0.96	0.60416667	0.58	45	2.82	3.69	0.47	FAILURE
11	1401470	0.78	1.99	1.391959799	2.77	42	3.6	2.49	0.8	1.32	1.21212121	1.6	142	3	2.5	0.8	SUCCESS
12	1400776	0.46	0.85	0.635294118	0.54	18	2.5	1.6	0.43	-	-	-	-	-	-	-	FAILURE
13	375369	1.9	1.6	0.925	1.48	60	2.9	2.8	2	1.7	1	1.7	62	2.9	2.9	2.1	SUCCESS
14	1217650	1.58	1.6	0.8	1.28	30	3.2	2.28	1.69	1.7	0.76470588	1.3	42	3.2	2.3	1.68	SUCCESS
15	1221382	1.7	1	1.03	1.03	236	2.9	2.7	1.69	1.09	1.02752294	1.12	240	2.9	2.7	1.7	SUCCESS
16	1207617	1	1.31	0.664122137	0.87	3.9	2.98	2.9	1.43	-	-	-	-	-	-	-	FAILURE
17	1186117	0.92	1.3	1.915384615	2.49	39	3.2	2.8	0.9	-	-	-	-	-	-	-	FAILURE
18	1212603	1.5	1.58	0.987341772	1.56	106	4.3	3.5	1.56	-	-	-	-	-	-	-	FAILURE
19	493101	2.38	0.95	0.536842105	0.51	21.4	2.6	2.4	2.4	-	-	-	-	-	-	-	FAILURE
20	1213334	2.87	1.15	0.930434783	1.07	18.75	3.7	3.61	2.89	-	-	-	-	-	-	-	FAILURE
21	1212014	1.78	1.44	1.055555556	1.52	28	2.3	2.4	1.78	1.44	1.24305556	1.79	25	2.4	2.5	1.8	SUCCESS
22	1202011	0.6	2.04	2.039215686	4.16	24	4.56	4.04	0.65	2.1	1.6047619	3.37	30	4.5	4.1	0.94	SUCCESS
23	1208649	2.1	1.6	1.2	1.92	66	2	1.9	2	1.8	1.2	2.16	72	2.1	1.9	2.1	SUCCESS
24	860837	1.7	1.6	1.075	1.72	42	2.6	2.4	1.8	1.75	1.01714286	1.78	48	2.8	2.6	1.89	SUCCESS
25	1208961	1.35	1.29	0.713178295	0.92	29	2.38	2.03	1.18	1.49	1.06040268	1.58	30.7	2.63	2.45	1.2	SUCCESS
26	1202632	1.86	1.51	0.582781457	0.88	10.2	4.56	4.83	1.89	1.6	0.8	1.28	12	4.56	4.83	1.89	SUCCESS
27	1207447	2.6	1.87	0.50802139	0.95	87	3.4	3.3	2.56	2.04	0.87254902	1.78	93	3.9	3.7	2.9	SUCCESS
28	1205443	0.93	0.7	0.5	0.35	0	2.9	4.4	0.54	-	-	-	-	-	-	-	FAILURE
29	1107364	2.09	2.04	0.911764706	1.86	45	3.52	3.65	1.8	2.4	0.95833333	2.3	58	3.5	3.4	1.96	SUCCESS
30	1205382	2.7	1.28	0.984375	1.26	40	3.4	3.3	2.6	1.5	1.08	1.62	56	3.4	3.3	2.6	SUCCESS
31	1448506	0.73	1.68	1.023809524	1.72	30	1.6	1.54	0.72	1.69	1.01775148	1.72	43	1.5	1.52	0.7	SUCCESS
32	1445183	0.52	1.72	0.988372093	1.7	38	2.09	2.1	0.6	1.77	1.02824859	1.82	44	2	2.1	0.75	SUCCESS
33	1445210	0.89	1.2	1.116666667	1.34	29	2.5	1.8	0.78	1.24	0.96774194	1.2	37	2.4	1.9	0.78	SUCCESS
34	1440358	0.63	1.9	0.894736842	1.7	36	1.7	1.74	0.67	2.2	1.13636364	2.5	44	1.6	1.6	0.64	SUCCESS
35	1429305	1.2	1.1	1.181818182	1.3	21	3.6	4.2	1.6	-	-	-	-	-	-	-	FAILURE
36	365902	1.9	1.3	0.769230769	1	18	3.6	4.3	2.89	-	-	-	-	-	-	-	FAILURE
37	349317	0.96	1.5	1.133333333	1.7	40	2.2	1.8	1	1.3	1.15384615	1.5	44	2	1.6	1.1	SUCCESS
38	458582	0.49	1.5	1.2	1.8	48	1.3	1.2	0.7	1.7	1.29411765	2.2	56	1.2	1.1	0.7	SUCCESS
39	144297	0.88	1.4	0.857142857	1.2	60	1.8	1.7	0.89	1.6	0.875	1.4	72	1.6	1.5	0.88	SUCCESS
40	1444595	0.54	1.8	1.333333333	2.4	76	1.4	1.3	0.68	2.1	1.14285714	2.4	96	1.2	1.3	0.88	SUCCESS

S. NO	MRD	AGE (years)	AGE GROUP	SEX	BMI	BMI GROUP	DAYS ON MV	REASON FOR ICU ADMSSN	CO MORBIDITIES	SOFA	GCS	MRC MUSCLE POWER	RSBI
41	1443241	69	5	M	28	3	14	S/P EL for enteric perforation	DM	8	11	3	45
42	1424505	52	4	M	26	3	5	S/P pancreatic necrosectomy	-	8	11	4	26
43	1424498	50	3	F	24	2	6	S/P EL for mesentric ischemia	-	7	11	5	42
44	1450577	48	3	M	23	2	6	S/P Pancreatic necrosectomy	-	8	11	5	55
45	1450320	26	1	F	22	1	6	Acute liver failure (HAV reactive)	-	9	11	5	34
46	1212740	72	6	M	24	2	14	COPD exacerbation LRTI	DM,HTN	9	11	4	77
47	1453273	45	3	M	26	3	6	Polytrauma BTC Lung contusions	-	6	11	5	42
48	1448991	34	2	F	27	3	14	Pancreatitis S/P necrosectomy	DM	9	11	5	45
49	1447879	38	2	M	26	3	9	S/P pancreatic necrosectomy	-	9	11	5	43
50	1451849	62	5	F	23	2	14	S/P ilesotomy for enteric perforation	-	7	11	4	45
51	1308089	35	2	M	27	3	2	Septic shock diabetic foot	DM	6	11	5	55
52	1308082	30	1	M	24	2	10	S/P pancreatic necrosectomy	-	9	11	4	60
53	1301122	35	2	M	27	3	2	Mesentric tear repair(Polytrauma)	-	7	11	5	60
54	1301437	65	5	M	23	2	2	S/P appendicular mass biopsy and proximal ilestomy	DM	3	11	5	44
55	1303023	48	3	M	29	3	2	S/P maxillofacial injury repair with TBI	-	2	11	5	32
56	1302405	50	3	M	30	4	4	Chest trauma with hydropneumothorax with multiple ribs and scapula #	-	5	11	5	54
57	966548	30	1	M	27	3	14	Polytrauma with with ARDS	-	10	11	4	78
58	1288459	60	4	F	23	2	6	Enteric perforation S/P laprotomy	-	4	11	4	45
59	1299609	34	2	M	26	3	4	S/P pancreatic necrosectomy	-	6	11	5	44
60	1282279	35	2	M	28	3	2	S/P abdominoperineal resection for Ca rectum	-	2	11	5	34
61	1284940	36	2	F	20	1	7	Polytrauma S/P Bladder repair and ORIF femur #	-	6	11	5	44
62	1268915	65	5	M	28	3	10	Pancreatitis with ARDS	-	7	11	5	32
63	1279064	45	3	M	27	3	6	SDH S/P decompressive craniotomy	-	6	9	-	34
64	701798	54	4	F	27	3	8	SDH S/P decompressive craniotomy	HTN	3	9	-	44
65	1271032	28	1	F	24	2	8	Acute liver failure (HAV reactive)	-	6	11	5	32
66	1256941	56	4	M	29	3	4	S/P decompressive craniotomy for acute SDH	-	3	8	-	43
67	1258918	68	5	M	29	3	5	S/P decompressive craniotomy for acute SDH	-	3	9	-	42
68	1268774	32	2	M	28	3	5	S/P decompressive craniotomy for acute SDH	HTN	3	9	-	56
69	1271898	56	4	M	32	4	8	Acute exacerbation of COPD with LRTI	HTN	2	11	5	43
70	1251161	65	5	M	30	4	3	S/P ilesotomy for enteric perforation	-	4	11	4	23
71	1232880	60	4	M	26	3	2	S/P esophagectomy	-	2	11	5	45
72	1235273	35	2	F	24	2	3	S/P LSCS PPH, Septic shock	-	5	11	5	54
73	1277984	45	3	M	30	4	4	S/P maxillofacial injury repair, polytrauma	-	4	11	5	34
74	1394332	56	4	F	30	4	14	Pancreatitis with ARDS	-	6	11	4	43
75	1358236	45	3	M	30	4	2	S/P appendicectomy for appendicular perforation	COPD	4	11	5	23
76	460901	47	3	M	28	3	4	S/P Pancreatic necrosectomy	-	7	11	5	43
77	1288549	54	4	M	31	4	5	Polytrauma	-	4	11	5	24
78	1269015	36	2	M	26	3	12	S/P pancreatic necrosectomy	-	8	11	4	22
79	1290873	56	4	F	32	4	4	S/P laprotomy for mesentric ischemia	-	7	11	5	43
80	1154708	62	5	M	22	1	3	S/P laprotomy with appendicular biopsy for appendicular mass	-	5	11	5	21

S. NO	MRD	LUNG MECHANICS P0.1	NIF	TLC	HB	ALBUMIN	EF(%)	BNP	CALCIUM	POTASSIUM	PHOSPHORUS	CAM ICU	ON MECHANICAL VENTILATION DE (cm)	ON MV INSPIRATORY TIME(Ti) sec	ON MECHANICAL VENTILATION DETI(cmsec)	ON MECHANICAL VENTILATION DTF(%)	ON MECHANICAL VENTILATION PCV	ON MECHANICAL VENTILATION PRV
41	1443241	2	-19	15	8	2.7	60	230	7	4	3	pos	2.04	0.882352941	1.8	22	3.1	2.6
42	1424505	3	-27	8	8.7	2.6	60	98	7	3.8	2.2	neg	1.8	0.872222222	1.57	31	1.5	1.5
43	1424498	3	-22	12	7	2.5	60	45	7.6	3.7	2.4	neg	1.55	1.096774194	1.7	43	2.1	2.2
44	1450577	4	-20	15	7.6	2.4	55	56	7.6	3.7	2.2	pos	1.9	1.052631579	2	32	1	0.9
45	1450320	4	-25	14	8.8	2.6	60	56	7.7	4.3	2.7	pos	1.2	0.833333333	1	28	1.2	1.3
46	1212740	3	-17	16	8.2	2.4	60	67	8.1	3.7	2	pos	0.7	1.142857143	0.8	17	3.1	2.6
47	1453273	2	-24	17	8	2.7	60	56	7.8	3.7	2.1	neg	1.3	1.153846154	1.5	29	1.8	1.8
48	1448991	3	-23	15	9	2.5	45	100	6.5	3.6	2.1	pos	1.9	0.884210526	1.68	34	2.6	2.5
49	1447879	3	-25	14	8.8	2	45	89	7.8	2.7	1.9	pos	2.2	1.090909091	2.4	28	1.4	1.5
50	1451849	4	-12	16	7.9	2.8	45	88	7.9	4.6	2.7	pos	0.51	0.509803922	0.26	10.5	2.9	2.8
51	1308089	4	-27	14	7.8	3	60	88	8	3.8	2.2	neg	1.55	1.032258065	1.6	32	1.5	1.5
52	1308082	3	-23	15	8.8	3.1	60	66	7.2	4.1	2.2	neg	1.1	0.909090909	1	28	2.1	2.2
53	1301122	3	-26	14	8	3.2	60	75	8.8	3.6	1.8	neg	1.9	0.842105263	1.6	66	2.9	2.2
54	1301437	3	-22	15	8.9	2.8	60	76	8.9	3.14	2.1	neg	1.8	0.888888889	1.6	56	1.28	1.4
55	1303023	2	-30	14	9	3	60	34	8.9	3.9	2.7	neg	2.5	0.8	2	67	2.9	1.9
56	1302405	4	-27	12	9	3.4	60	11	8.8	3.8	2.4	neg	2.1	0.857142857	1.8	44	1.8	1.7
57	966548	5	-18	14	9	3.2	60	100	8.5	3.9	2	pos	0.8	0.75	0.6	12	2.9	3.9
58	1288459	3	-23	14	8	2.8	60	45	8.7	3.4	1.7	pos	1.2	1.166666667	1.4	24	2.2	2.4
59	1299609	3	-26	12	8.9	2.5	60	67	8.7	3.8	2	neg	1.6	1.125	1.8	45	2.2	2.3
60	1282279	3	-24	17	8.8	3	60	76	8.8	4	3	neg	1.4	1.285714286	1.8	56	1.6	1.5
61	1284940	3	-26	14	8.8	2.4	60	44	7.5	3.6	2	neg	2.2	0.909090909	2	66	1.4	1.5
62	1268915	4	-24	12	8.9	3	60	32	6	3.5	2	pos	1.9	0.842105263	1.6	45	1.9	1.8
63	1279064	3	-	10	9	3.5	60	45	8.8	4	2.7	-	1.4	1.142857143	1.6	56	2.1	2.2
64	701798	3	-	12	8	3	60	44	8.8	3.8	2.6	-	1.6	1.125	1.8	78	2	2.1
65	1271032	3	-25	12	10	2.8	60	65	8.9	4	2	pos	1.5	1	1.5	54	1.8	1.9
66	1256941	2	-	14	10	3	60	24	8.8	3.6	2.2	-	1.9	0.894736842	1.7	64	2.1	2.3
67	1258918	3	-	12	9	3.1	60	22	8.4	4.3	2.7	-	1.2	1.166666667	1.4	36	1.2	1.3
68	1268774	2	-	11	8.7	3.2	60	56	8.2	3.8	2.2	-	1.3	1.076923077	1.4	58	1.6	1.7
69	1271898	1	-24	14	8.9	2.9	60	120	8.8	3.5	2	neg	1.28	1.015625	1.3	28	1.2	1.3
70	1251161	2	-24	13	8	2.8	35	100	8.9	3.8	2.3	pos	1.2	1.166666667	1.4	22	1.9	1.9
71	1232880	3	-26	20	8	2.9	60	38	8.9	3.6	2.9	neg	1.5	0.933333333	1.4	28	2.5	2.4
72	1235273	4	-30	16	8.8	2.4	60	38	8.8	5	2.2	neg	2.4	0.75	1.8	45	2.3	2.2
73	1277984	3	-29	12	8.9	2.8	60	54	8.9	3.9	2	neg	2.1	1.095238095	2.3	34	2.4	2.3
74	1394332	4	-23	10	8.9	2.8	45	24	7.8	3.8	2.9	pos	0.7	0.6	0.42	14	4.3	4.4
75	1358236	2	-26	14	8	3	56	56	7.6	3.6	2.2	neg	1.55	0.903225806	1.4	34	1.8	1.7
76	460901	4	-25	15	7.8	3	60	69	7.2	4.2	1.8	pos	1.9	0.842105263	1.6	56	2.1	2.2
77	1288549	3	-24	12	8.4	2.8	60	78	7.9	3.9	3	neg	1.2	1.083333333	1.3	34	1.3	1.5
78	1269015	4	-22	16	8.2	2.8	60	76	8.1	2.8	2.6	pos	1.4	1.071428571	1.5	28	2.7	2.5
79	1290873	4	-22	12	7.8	2.6	60	56	7.7	2.9	2.1	neg	1.6	0.875	1.4	35	2.7	2.9
80	1154708	4	-26	16	8	2.8	60	79	7.8	3.6	1.9	pos	1.4	0.857142857	1.2	44	1.8	1.9

S. NO	MRD	ON MECHANICAL VENTILATION VTI	30MINS OF WEANING TRIAL DE	30 MIN WEANING TRIAL Ti(sec)	30MINS OF WEANING TRIAL DETI	30MINS OF WEANING TRIAL DTF(%)	30MINS OF WEANING TRIAL PCV	30MINS OF WEANING TRIAL PRV	30MINS OF WEANING TRIAL VTI	24 HRS OF WEANING TRIAL DE	24 HRS WEANING Ti (sec)	24 HRS OF WEANING TRIAL DETI	24 HRS OF WEANING TRIAL DTF(%)	24 HRS OF WEANING TRIAL PCV	24 HRS OF WEANING TRIAL PRV	24 HRS OF WEANING TRIAL VTI	OUTCOME
41	1443241	0.9	1.65	0.993939394	1.64	23	3.4	2.2	1	-	-	-	-	-	-	-	FAILURE
42	1424505	0.73	2.1	1.152380952	2.42	32	1.28	0.9	0.72	2.2	1.07272727	2.36	39	1.8	1.8	0.78	SUCCESS
43	1424498	0.96	1.7	1.058823529	1.8	44	1.7	1.8	0.94	1.8	1.11111111	2	52	1.8	2.2	0.92	SUCCESS
44	1450577	0.49	2.3	1.043478261	2.4	34	1.3	1.4	0.6	2.4	1.08333333	2.6	42	1.4	1.7	0.6	SUCCESS
45	1450320	0.56	1.3	0.923076923	1.2	30	1.3	1.4	0.52	1.5	1.13333333	1.7	36	1.2	1.2	0.55	SUCCESS
46	1212740	1.11	0.8	1.25	1	18	3	2.8	1.1	-	-	-	-	-	-	-	FAILURE
47	1453273	0.88	1.7	0.941176471	1.6	28	1.9	1.9	0.89	2	1.1	2.2	32	2	2.1	0.88	SUCCESS
48	1448991	1.2	1.8	0.888888889	1.6	36	2.4	2.2	1.1	2.1	1.04761905	2.2	40	2.2	2.1	1	SUCCESS
49	1447879	1.74	1.9	1.157894737	2.2	30	1.4	1.2	1.72	2.2	1	2.2	28	1.2	1.1	1.7	SUCCESS
50	1451849	1.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	FAILURE
51	1308089	0.73	1.6	0.75	1.2	28	1.5	1.7	0.89	1.8	0.88888889	1.6	40	1.3	1.2	0.72	SUCCESS
52	1308082	0.96	1.2	1	1.2	32	2.2	2.4	1	1.8	0.77777778	1.4	44	2.2	2.2	1.1	SUCCESS
53	1301122	1.5	2.2	0.818181818	1.8	68	2.8	2	1.5	2.4	0.83333333	2	112	2.7	2.2	1.2	SUCCESS
54	1301437	1.4	1.9	0.789473684	1.5	54	1.4	1.5	1.2	2.2	1.09090909	2.4	80	1.4	1.5	1.2	SUCCESS
55	1303023	1.4	2.4	0.916666667	2.2	68	2.8	2	1.4	2.4	0.91666667	2.2	88	2.4	2.4	1.2	SUCCESS
56	1302405	1.4	1.8	1	1.8	42	1.9	1.9	1.5	2.2	0.90909091	2	54	1.8	1.8	1.4	SUCCESS
57	966548	2.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	FAILURE
58	1288459	1.6	1.1	0.727272727	0.8	20	2.4	2.5	1.8	1.4	1.14285714	1.6	30	2	2.1	1.6	SUCCESS
59	1299609	1.5	1.5	1.2	1.8	44	2.3	2.4	1.6	1.7	1	1.7	54	2.2	2.2	1.5	SUCCESS
60	1282279	0.96	1.2	0.833333333	1	60	1.8	1.8	1.2	1.4	1.14285714	1.6	96	1.6	1.6	1	SUCCESS
61	1284940	1	2	1.1	2.2	72	1.6	1.6	1.2	2.2	1.09090909	2.4	102	1.2	1.3	0.92	SUCCESS
62	1268915	1.4	1.8	0.888888889	1.6	38	1.9	1.8	1.6	2.2	1.09090909	2.4	66	1.6	1.5	1.4	SUCCESS
63	1279064	1.2	1.4	0.857142857	1.2	46	2.4	2.5	1.5	1.8	1	1.8	88	2	2.1	1.2	SUCCESS
64	701798	1	1.6	0.875	1.4	66	2.1	2.1	1.2	1.8	1	1.8	88	2.1	2.1	1	SUCCESS
65	1271032	1.2	1.4	0.857142857	1.2	50	2	2.1	1.4	1.8	1.11111111	2	66	1.8	1.8	1.1	SUCCESS
66	1256941	1.99	1.6	0.875	1.4	70	2.4	2.6	2.2	1.9	1.15789474	2.2	88	2.1	2.2	1.8	SUCCESS
67	1258918	0.96	1.2	1	1.2	34	1.4	1.4	1.1	1.6	1.125	1.8	40	1.3	1.2	1	SUCCESS
68	1268774	1.1	1.2	0.833333333	1	58	1.8	1.9	1.2	1.5	1.13333333	1.7	66	1.4	1.5	1.1	SUCCESS
69	1271898	1.1	1.3	0.923076923	1.2	20	1.4	1.5	1.2	1.4	1.14285714	1.6	38	1.2	1.3	1.1	SUCCESS
70	1251161	1.6	1.1	0.909090909	1	20	2.2	2.3	1.8	1.3	1.07692308	1.4	28	1.8	1.9	1.6	SUCCESS
71	1232880	1.8	1.4	0.857142857	1.2	26	2.4	2.3	1.9	1.7	1.11764706	1.9	35	2.2	2.3	1.7	SUCCESS
72	1235273	1.6	2.2	0.772727273	1.7	44	2.2	2.4	1.9	2.2	1.09090909	2.4	67	2.1	2.2	1.7	SUCCESS
73	1277984	1.7	2	1.05	2.1	32	2.3	2.4	1.8	2.2	1.18181818	2.6	46	2.2	2	1.6	SUCCESS
74	1394332	2.5	0.8	0.6	0.48	12	4.4	4.3	2.6	-	-	-	-	-	-	-	FAILURE
75	1358236	0.74	1.4	0.857142857	1.2	35	1.9	2	1	1.7	1.11764706	1.9	43	1.6	1.7	0.8	SUCCESS
76	460901	1.4	1.6	0.9375	1.5	56	2.3	2.2	1.5	2.1	1.04761905	2.2	78	2.1	2.1	1.3	SUCCESS
77	1288549	1	1.1	0.909090909	1	38	1.5	1.6	1.2	1.4	0.85714286	1.2	42	1.6	1.7	1.3	SUCCESS
78	1269015	1.2	1.2	0.916666667	1.1	29	2.9	3.1	1.5	1.5	1.13333333	1.7	44	2.5	2.2	1.2	SUCCESS
79	1290873	1.8	1.7	1.117647059	1.9	39	2.9	3	1.9	1.8	1.11111111	2	44	2.6	2.7	1.7	SUCCESS
80	1154708	1.4	1.5	1	1.5	54	1.9	2	1.1	1.8	1.05555556	1.9	67	1.7	1.8	1.2	SUCCESS

S. NO	MRD	AGE (years)	AGE GROUP	SEX	BMI	BMI GROUP	DAYS ON MV	REASON FOR ICU ADMSSN	CO MORBIDITIES	SOFA	GCS	MRC MUSCLE POWER	RSBI
81	1391967	34	2	M	26	3	12	Viral pneumonitis with severe ARDS	-	7	11	5	48
82	1398742	62	5	F	24	2	16	S/P enteric perforation repair	-	7	11	3	56
83	841089	23	1	F	24	2	5	S/P laprotomy for perfoartion peritonitis	-	8	11	5	54
84	1395251	56	4	M	27	3	2	S/P whipples procedure with pacemaker in situ	-	4	11	5	27
85	131359	45	3	M	24	2	14	Polytrauma with traumatic pancreatitis	-	8	11	4	43
86	1371217	64	5	M	24	2	8	Acute necrotising pancreatitis with PCD in situ	-	8	11	4	65
87	1356802	34	2	M	25	3	10	Polytrauma with ARDS in sepsis resolving	-	7	10	-	32
88	1396171	56	4	M	28	3	6	S/P decompressive craniotomy for acute SDH	-	5	9	-	54
89	1330268	52	4	M	29	3	3	S/P appendicectomy for appendicular perforation	-	4	11	5	32
90	1370834	45	3	M	29	3	6	S/P pancreatic necrosectomy	-	7	11	5	34
91	1356613	56	4	M	29	3	2	Polytrauma	-	6	11	4	44
92	1340154	29	1	M	23	2	6	S/P pancreatic necrosectomy	-	7	11	4	32
93	1328744	40	2	M	32	4	2	S/P maxillofacial injury repair with TBI	-	3	11	5	46
94	1301122	40	2	M	28	3	8	S/p Pancreatic necrosectomy with septic shock	-	6	11	5	43
95	1356704	50	3	F	24	2	2	S/P Bed sore debridement in septic shock	-	7	11	4	43
96	1024788	45	3	M	29	3	7	S/P laprotomy for perfoartion peritonitis	-	7	11	5	42
97	682797	56	4	F	22	1	3	S/P laprotomy for ileal perforation	-	7	11	5	40
98	1299576	56	4	M	25	3	7	S/P laprotomy for intestinal obstruction	CLD	8	11	4	56
99	1304232	80	6	F	20	1	3	S/P laprotomy for intestinal obstruction	-	2	11	4	24
100	1297514	56	4	M	30	4	7	S/P pancreatic necrosectomy in septic shock	-	7	11	5	44

S. NO	MRD	LUNG MECHANICS P0.1	NIF	TLC	HB	ALBUMIN	EF(%)	BNP	CALCIUM	POTASSIUM	PHOSPHORUS	CAM ICU	ON MECHANICAL VENTILATION DE (cm)	ON MV INSPIRATORY TIME(Ti) sec	ON MECHANICAL VENTILATION DETI(cmsec)	ON MECHANICAL VENTILATION DTF(%)	ON MECHANICAL VENTILATION PCV	ON MECHANICAL VENTILATION PRV
81	1391967	5	-24	16	7	3.1	40	120	8.8	4.1	3.2	pos	1.2	0.833333333	1	28	1.9	2
82	1398742	1	-20	15	8	3.2	60	67	7.9	3.8	2.9	pos	0.9	0.777777778	0.7	10.5	4.3	4.5
83	841089	4	-25	17	7.8	2.9	60	75	7.8	2.9	2.7	neg	1.8	0.888888889	1.6	89	2.9	2.8
84	1395251	3	-25	12	9	3.2	60	89	7.5	3.9	2.1	pos	1.2	0.916666667	1.1	22	2.89	2.9
85	131359	5	-24	14	8.9	2.9	60	59	7.8	3.2	1.9	pos	1.1	0.818181818	0.9	21	3.3	3.4
86	1371217	4	-26	15	8.8	2.9	60	67	8.8	4	1.9	pos	1.4	0.857142857	1.2	28	2.8	2.7
87	1356802	5	-26	15	8.9	2.9	60	68	8.7	3.9	1.8	-	1.3	0.846153846	1.1	29	3.8	3.8
88	1396171	3	-	12	9	3.6	60	67	8.9	2.9	2.2	-	1.5	1.066666667	1.6	56	1.9	1.8
89	1330268	4	-20	14	10	3	60	78	8.8	3.6	3.1	neg	1.6	1.0625	1.7	54	1.6	1.5
90	1370834	3	-22	16	8	3	60	88	7.8	3.9	2.8	pos	0.9	0.777777778	0.7	19	4	2.2
91	1356613	3	-23	14	9	3.2	60	90	8.8	4.2	3.2	neg	1.9	0.842105263	1.6	44	2.6	3
92	1340154	3	-25	14	8.7	3.4	60	69	8.8	4	3.2	pos	1.5	0.8	1.2	29	3.2	3.1
93	1328744	4	-26	15	8.8	3	60	89	8.9	3.8	2.3	neg	1.6	0.875	1.4	38	2.3	2.4
94	1301122	5	-22	17	7.8	3.2	60	54	7.9	4.2	2.8	pos	1.2	0.833333333	1	28	1.8	1.5
95	1356704	2	-21	15	8	2.9	60	54	8.2	3.9	2.2	pos	1.2	0.833333333	1	24	1.2	1
96	1024788	3	-24	16	8.8	2.6	60	45	8	3.5	2	neg	1.2	0.916666667	1.1	28	1.9	1.7
97	682797	2	-20	20	8	1.7	60	45	8	3.8	2	pos	1.4	0.857142857	1.2	25	1.9	2
98	1299576	2	-20	16	8	2.2	28	400	8	3.9	1.8	pos	1.3	1.076923077	1.4	22	2.5	2.6
99	1304232	3	-24	18	8.8	3	60	87	7.8	3.8	2	neg	1.8	0.888888889	1.6	30	2.1	2.2
100	1297514	4	-25	12	8.8	2.9	60	56	8.2	3.7	2.2	neg	2.1	0.857142857	1.8	30	2	2.1

S. NO	MRD	ON MECHANICAL VENTILATION VTI	30MINS OF WEANING TRIAL DE	30 MIN WEANING TRIAL Ti(sec)	30MINS OF WEANING TRIAL DETI	30MINS OF WEANING TRIAL DTF(%)	30MINS OF WEANING TRIAL PCV	30MINS OF WEANING TRIAL PRV	30MINS OF WEANING TRIAL VTI	24 HRS OF WEANING TRIAL DE	24 HRS WEANING Ti (sec)	24 HRS OF WEANING TRIAL DETI	24 HRS OF WEANING TRIAL DTF(%)	24 HRS OF WEANING TRIAL PCV	24 HRS OF WEANING TRIAL PRV	24 HRS OF WEANING TRIAL VTI	OUTCOME
81	1391967	1	1	0.8	0.8	20	2.4	2.6	1.9	-	-	-	-	-	-	-	FAILURE
82	1398742	2.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	FAILURE
83	841089	1.8	1.7	1.058823529	1.8	96	3.1	3.2	2.2	2.2	1.09090909	2.4	108	2.7	2.8	1.9	SUCCESS
84	1395251	2	1.2	1.166666667	1.4	32	2.9	3	2.2	1.6	1.125	1.8	46	2.7	2.8	2	SUCCESS
85	131359	2.8	1	0.9	0.9	24	3.6	3.5	2.9	-	-	-	-	-	-	-	FAILURE
86	1371217	1.2	1.3	0.923076923	1.2	29	2.9	2.9	1.4	1.6	1.125	1.8	32	2.8	2.8	1.3	SUCCESS
87	1356802	2.9	1.2	0.833333333	1	22	3.9	4	2.9	-	-	-	-	-	-	-	FAILURE
88	1396171	1.2	1.6	1.0625	1.7	60	2	2.1	1.4	1.8	1.11111111	2	88	1.8	1.7	1.1	SUCCESS
89	1330268	0.78	1.6	0.875	1.4	57	1.8	1.9	0.8	1.9	1.05263158	2	88	1.9	1.8	0.8	SUCCESS
90	1370834	3	1	0.8	0.8	20	4.2	4.3	3.2	-	-	-	-	-	-	-	FAILURE
91	1356613	2	1.8	0.833333333	1.5	40	2.7	2.9	1.9	1.9	1.15789474	2.2	67	2.5	2.6	1.8	SUCCESS
92	1340154	2.4	1.3	0.846153846	1.1	24	2.8	2.9	2.1	-	-	-	-	-	-	-	FAILURE
93	1328744	1.3	1.4	0.857142857	1.2	40	1.8	1.9	1.4	1.8	1.11111111	2	56	1.6	1.8	1.5	SUCCESS
94	1301122	1.1	1.4	0.928571429	1.3	30	1.9	1.8	1.3	1.6	1.0625	1.7	44	1.8	1.7	1.2	SUCCESS
95	1356704	0.7	1.3	1.076923077	1.4	23	1.2	1.1	0.8	1.4	1.14285714	1.6	26	1.1	1.2	0.7	SUCCESS
96	1024788	1.2	1.2	0.833333333	1	22	2	1.8	1.4	-	-	-	-	-	-	-	FAILURE
97	682797	0.9	1.4	0.785714286	1.1	22	2	1.8	1.2	1.8	1.11111111	2	30	1.9	1.9	1	SUCCESS
98	1299576	1.4	1.2	0.916666667	1.1	18	2.8	2.7	1.6	-	-	-	-	-	-	-	FAILURE
99	1304232	1.3	1.7	0.941176471	1.6	32	2.4	2.5	1.4	2	1.1	2.2	44	2.1	2.2	1.1	SUCCESS
100	1297514	0.56	2	0.9	1.8	32	2.4	2.6	0.8	2.2	1.07272727	2.36	46	2.1	2.2	0.6	SUCCESS

Baba Farid University
of Health Sciences
Sadiq Road
Faridkot-151 203 (Pb.) INDIA
Phone : 01639-256232, 256236
Tele/Fax : 01639-256235
Email : Examination@bfuhs.ac.in

No. BFUHS/2K21p-III/ 129 Date 05/01/22

The Principal,
DMC, Ludhiana.

Subject: Approval of Plan of Thesis.

This is to inform you that the Faculty of Medical Sciences in its meeting held on 29.10.2021 has approved the plan of thesis of **Apoorva Gupta**, a student of your college for **DM Critical Care Medicine** along with the names of Supervisor/Co-Supervisor as under:-

Topic Plan of Thesis

Evaluation of diaphragm ultrasonography in predicting weaning outcomes from mechanical ventilation.

Supervisor

Dr. Gunchan Paul
Assoc. Prof.,
Dept. of Critical Care Medicine,
DMCH, Ludhiana.

Co-Supervisor

Dr. Parshotam Lal Gautam
Prof. & Head,
Dept. of Critical Care Medicine,
DMCH, Ludhiana.

The student has to submit the four copies of thesis (along with PDF format) , to the Controller of Examinations, BFUHS, Faridkot, at least six months before the commencement of theory examination, if he/she is otherwise eligible to take the examination. He /She must directed to attach a photocopy of this letter with the forwarding letter while submitting thesis to the University along with the letter of approval of University for change of supervisor/Co-Supervisor, change of topic,(if any).

Dr. S P Singh MS(Oph)
Controller of Examinations

Note :

159. If any discrepancy found regarding topic of thesis or Supervisor/Co-Supervisor, inform undersigned within one month after issue of this letter.

160. The student may submit the thesis as per the schedule already conveyed i.e for May/June examination 30th Nov of the preceding the year of examination and for Nov/Dec examinations 31st May of the year of examination.

EVALUATION OF DIAPHRAGM ULTRASONOGRAPHY IN PREDICTING WEANING OUTCOMES FROM MECHANICAL VENTILATION

THESIS PROPOSAL

FOR APPROVAL OF SUBJECT OF THESIS TO BE SUBMITTED

IN PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

DOCTORATE OF MEDICINE

IN

CRITICAL CARE MEDICINE

OF THE

BABA FARID UNIVERSITY OF HEALTH SCIENCES
FARIDKOT

JULY, 2021

DR APOORVA GUPTA

DEPARTMENT OF CRITICAL CARE MEDICINE
DAYANAND MEDICAL COLLEGE & HOSPITAL
LUDHIANA

ABSTRACT OF PLAN OF THESIS

Title	EVALUATION OF DIAPHRAGM ULTRASONOGRAPHY IN PREDICTING WEANING OUTCOMES FROM MECHANICAL VENTILATION
For the degree of	D.M. CRITICAL CARE MEDICINE
Name of the candidate	DR. APOORVA GUPTA
Supervisor	Dr. Gunchan Paul, Associate Professor, Department of Critical Care Medicine, DMCH, Ludhiana
Co-supervisor	Dr. Parshotam Lal Gautam, Professor & Head, Department of Critical Care Medicine, DMCH, Ludhiana
Institution	Dayanand Medical College & Hospital, Ludhiana
University	Baba Farid University of Health Sciences, Faridkot

Introduction: Investigating the causes of weaning failure is crucial because the duration of mechanical ventilation for those who fail the SBT and need re-intubation needed have both been associated with poor outcomes.

Aim of Study: To evaluate the role of different ultrasonographic parameters for prediction of weaning from mechanical ventilation

Materials & Methods: When the patient is ready for weaning, Diaphragmatic excursion time index (DETI), and Diaphragmatic excursion will be measured on mechanical ventilation.

Diaphragmatic excursion time index (DETI), TDI parameters, diaphragmatic thickness fraction and diaphragmatic excursion will be measured in patients who have been on invasive mechanical ventilation for more than 24 hours, and are being given a weaning trial, after half an hour. The above mentioned indices will again be measured after 24 hours. Weaning success will be considered if neither invasive nor non-invasive ventilatory support is required for 48 hrs after weaning.

Clinical Significance: To find out the significance of different diaphragm ultrasound parameters in weaning prediction in patients being weaned from invasive mechanical ventilation

Keywords: Tissue Doppler Imaging, Diaphragm Excursion Time Index.

(Signature) Candidate	(Signature) Co-supervisor	(Signature) Supervisor	(Signature) Principal

CERTIFICATE OF FACILITIES AVAILABLE

This is to certify that the facilities for work on the subject of thesis titled **"EVALUATION OF DIAPHRAGM ULTRASONOGRAPHY IN PREDICTING WEANING OUTCOMES FROM MECHANICAL VENTILATION"** exist in the Department of Critical Care Medicine, DMC&H, Ludhiana and will be provided to the candidate. We will see that the data being included in the thesis is genuine and is collected by the candidate himself/herself under our supervision and guidance.

Supervisor

Gunchan Paul

Dr. Gunchan Paul
Associate Professor
Department of Critical Care Medicine
DMCH, Ludhiana

Co-Supervisors

Dr. Parshotam Lal Gautam
Professor & Head
Department of Critical Care Medicine
DMCH, Ludhiana

Head of the Department

Dr. Parshotam Lal Gautam
Professor & Head
Department of Critical Care Medicine
DMCH, Ludhiana

Place : Ludhiana

Date : 28-8-21.

APPROVAL PROFORMA
BY RESEARCH & ETHICAL COMMITTEE
DAYANAND MEDICAL COLLEGE & HOSPITAL, LUDHIANA

Name of candidate	Dr. Apoorva Gupta
Department	Critical Care Medicine
Topic of Thesis	EVALUATION OF DIAPHRAGM ULTRASONOGRAPHY IN PREDICTING WEANING OUTCOMES FROM MECHANICAL VENTILATION
Likely date of appearing in PG examination	August, 2023
Date of enrollment	30th December 2020
Name of Head of Department	Dr. Parshotam Lal Gautam
1) Supervisor **2) Co-Supervisor**	Dr. Gunchan Paul Dr. Parshotam Lal Gautam
Signature of Members of Research Committee with Stamp	**Signature of Members of Ethics Committee with Stamp**
Dr. Harpreet Kaur (Professor & Head, Pathology)	Mr. R K Sharma (Legal Expert)
Dr. Jaspal Singh (Professor & Head, Surgery)	Dr. Ramit Mahajan (Associate Professor, Gastroenterology)
Dr. Dinesh Gupta (Professor & Head, Medicine)	Dr. Anu Sharma (Professor, Anatomy)
Dr. Sandeep Kaushal (Dean Academics & Professor & Head, Pharmacology)	Dr. Sandeep Kaushal (Dean Academics & Professor & Head, Pharmacology)
Dr. Gurpreet S Wander (Vice Principal)	Dr. Gurpreet S Wander (Vice Principal & Professor & Head, Cardiology)
	Dr. Gagandeep Singh (Secretary, Ethics Committee Professor & Head, Neurology)

Approved: Yes / No

Dr. Sandeep Puri
Chairperson
Research Committee

Chairperson
Research Committee

Approved: Yes / ~~No~~

Prof. Arvind Malhotra
Chairperson
Ethics Committee

Chairperson
Committee

BABA FARID UNIVERSITY OF HEALTH SCIENCES, FARIDKOT

PROFORMA FOR REGISTRATION OF SUBJECT FOR DISSERTATION

1	NAME OF THE CANDIDATE AND ADDRESS	Dr. APOORVA GUPTA 1/309 Vaibhav khand Gomtinagar, Lucknow. -226010 U.P.
2	NAME OF THE INSTITUTE	DAYANAND MEDICAL COLLEGE AND HOSPITAL
3	COURSE OF STUDY AND SUBJECT	D.M. CRITICAL CARE MEDICINE
4	DATE OF ADMISSION OF COURSE	30th DECEMBER, 2020
5	TITLE OF THE TOPIC	EVALUATION OF DIAPHRAGM ULTRASONOGRAPHY IN PREDICTING WEANING OUTCOMES FROM MECHANICAL VENTILATION

6 BRIEF RESUME OF THE INTENDED WORK

6.1 NEED FOR THE STUDY

Investigating the causes of weaning failure is crucial because the duration of mechanical ventilation for those who fail the SBT [1] and need re-intubation needed [2,3] have both been associated with poor outcomes

Bedside ultrasonography has become a valuable tool in the management of intensive care unit patients [4]. This is especially true in emergency situations where an adequate imaging technique is frequently limited by a variety of factors, including difficulty of patient transportation to the radiology department due to illness severity. Ultrasonography is a noninvasive technique, which has proved to be an accurate, safe, easy to use bedside modality, overcoming many of the standard limitations of imaging techniques. The diaphragm is the principal respiratory muscle, and its dysfunction predisposes to respiratory complications and can prolong the duration of mechanical ventilation. Additional studies have confirmed that on average, 60% to 80% of mechanically ventilated patients manifest clinically significant diaphragm dysfunction.[5] Moreover, a recent study indicates that diaphragm weakness is present twice as often as limb weakness in critically ill patients.[5]

Sonographic evaluation of the diaphragm has recently started to gain popularity in the ICU as specific needs for assessing diaphragmatic function arise in many clinical situations. Abnormal diaphragmatic motion is observed in conditions such as phrenic nerve injury, neuromuscular diseases [6], after abdominal [7] or cardiac surgery [8] and in critically ill patients under mechanical ventilation [7]. Since diaphragmatic motion plays a prominent role in spontaneous respiration, observation of the diaphragm kinetics seems essential. The use of tools previously available for this purpose is limited due to the associated risks of ionizing radiation (fluoroscopy, computed tomography) or due to their complex and/or highly specialized nature, requiring a skilled operator (transdiaphragmatic pressure measurement, diaphragmatic electromyography, phrenic nerve

stimulation, magnetic resonance imaging). Sonography receives increasing recognition as a fast, easy and accurate method of noninvasively evaluating diaphragmatic function at the bedside. In the ICU population, it can quantify normal and abnormal movements in a variety of clinical conditions.

In recent years, ultrasonography has been used extensively to evaluate diaphragmatic motion characteristics, such as excursion and thickening [9], with derived measurements repeatedly being shown to carry prognostic implications in the outcome of weaning [8]. However, DETI and TDI of diaphragmatic tissue motion has been studied so far very little in adults [12]; In our study, we are looking forward to evaluate the role of newer diaphragmatic ultrasound parameters including DETI and TDI in conjugation with other parameters for predicting weaning outcomes in mechanically ventilated patients.

The day of extubation is a critical moment in the ICU stay. Despite meeting all weaning criteria and succeeding in a weaning trial, failure of planned extubation occurs in about 10–20% of cases [13], and patients who fail extubation have a high mortality ranging around 25–50% [14,15]. Although this high mortality rate may be ascribable to a greater severity at the time of extubation, there is some evidence that extubation failure and/or reintubation can directly worsen the patients ′outcome independently of their underlying severity [16].

Intensive care unit (ICU)-acquired weakness (ICUAW) is a complication observed in critically ill patients that combines myopathy and neuropathy[17]. Its incidence varies but may rise up to 100 % in patients with multiorgan failure[18]. It is associated with delayed weaning from mechanical ventilation (MV) , longer ICU stay, frailty and poor outcome . The diaphragm, the main inspiratory muscle, is also a victim of critical illness. However, the extent of diaphragmatic dysfunction compared to limb muscle weakness during critical illness is a matter of debate . Some studies have indeed reported particular diaphragm sensitivity to aggression while others have reported the opposite . MV by itself has been proven toimpair diaphragm force (a term labelled

ventilator-induced diaphragmatic dysfunction) and to promote diaphragm atrophy in the critically ill without affecting limb muscles.

Thus evaluation of the diaphragm as a predictor of weaning outcome is vital in the field of critical care medicine and the evaluation and subsequent validation of the newer parameters such as TDI and DETI can further help in a more accurate assessment of weaning outcomes there by preventing extubation failure.

6.2 REVIEW OF LITERATURE

Over the past decade, considerable clinical effort and research has focused almost entirely on ICU-acquired limb muscle weakness, with little emphasis on the diaphragm. It has been suggested that this may be due to a lack of knowledge regarding the effects of critical illness on the respiratory muscles or the limited availability of tools to assess and monitor diaphragm function in patients in the ICU.

Multiple recent studies have shown, however, that severe ICU-acquired diaphragm weakness develops in a large percentage of mechanically ventilated patients in the ICU.[9]

Unfortunately, despite the preponderance of evidence that respiratory muscle dysfunction is a common form of organ failure in critical illness and is associated with poor acute and long-term outcomes (discussed further on), clinicians frequently fail to consider this diagnosis. Theoretically, any patient who requires mechanical ventilation should be considered to be at risk for the development of diaphragm weakness.[10]

In addition, diaphragm dysfunction should be considered when a mechanically ventilated patient is making poor progress during weaning trials despite clinical improvements in pulmonary infiltrates, the lung examination, and several days of therapy (eg, administration of antibiotics or bronchodilators) to treat the underlying pulmonary disorder. The possibility of severe diaphragm weakness should also be entertained in patients with recurrent unexplained episodes of respiratory failure.

It is also extremely useful to assess simple bedside indices of lung and respiratory system function (ie, respiratory system static compliance, inspiratory airway resistance, and the rapid shallow breathing index [RSBI] in mechanically ventilated patients who are not making adequate progress.

The chest radiograph may also sometimes suggest the possibility of a significant diaphragm pathologic condition. Although not specific,[11] unilateral or bilateral hemidiaphragm elevation can be seen with diaphragm paralysis or severe weakness, and this finding should

prompt the use of simple tests (eg, diaphragm ultrasonography) to determine if diaphragm motion is adequate.

A final clinical situation that warrants consideration of severe diaphragm dysfunction is patients who have no prior history of lung disease who present with hypercapneic respiratory failure and a normal chest radiograph. In these instances, patients may have pre-existing undiagnosed primary neuromyopathic processes, such as amyotrophic lateral sclerosis, Guillain-Barre syndrome, chronic inflammatory demyelinating polyneuropathy, myasthenia gravis, carnitine deficiency, Pompe disease, polymyositis, orinclusion body myositis.Although there can be considerable heterogeneity in the presentation of many of these disorders, as well as marked variation in the severity of dysfunction from muscle to muscle, in some patients, acute respiratory failure due to respiratory muscle weakness may be the major presenting component of these diseases. Neurologic consultation is required for such patients. Several of these disorders are eminently treatable, and failure to diagnose these conditions represents a lost opportunity.

Although many practitioners assume that ICU-acquired diaphragm weakness is transient and does not directly affect patient outcomes, there are several recent studies indicating that diaphragm strength is a major determinant of both the time required to wean patients from mechanical ventilation and ICU mortality.

Diaphragm weakness has also been shown to correlate with higher mortality. Specifically, in one study, the incidence of ICU death was 49% in the patients with the weakest diaphragms (ie, with PdiTw < 10 cm H_2O) but only 7% for patient with stronger diaphragms (PdiTw levels > 10 cm H_2O; P = .022).[12] where PdiTw is the trandiaphragmatic twitch pressure generation. In fact, it has been reported that diaphragm weakness is a far stronger predictor of ICU mortality than the degree of organ failure, severity of lung function abnormalities, age, sex, steroid use, or the comorbidity index in mechanically ventilated patients.[19]There are several potential explanations for the association of mortality and diaphragm weakness. In some instances, sicker patients are more likely to have illnesses (eg,

sepsis) that both increase mortality (eg, shock) and lead to the use of ventilator settings that engender diaphragm weakness. As a result, in some cases, it could be argued that death may be due to the underlying disease process and that diaphragm weakness may represent an epiphenomenon. In other cases, however, patients requiring sustained mechanical ventilation may have care withdrawn when it proves difficult to wean these patients from the ventilator.[19] A recent analysis suggests that diaphragm weakness may be the main factor preventing liberation from mechanical ventilation in many of these patients; for this subgroup, it is likely that diaphragm weakness is causally related to death.[40] Additional work will be needed to confirm these results and fully assess the mechanisms and implications of these previous findings.

Causes of Diaphragm Dysfunction in Mechanically Ventilated Patients

When diaphragm weakness is found in mechanically ventilated patients, it is always important to first exclude the presence of easily treatable endocrine and electrolyte disorders such as hypophosphatemia, hypomagnesemia, and hypocalcemia.[12] Severe diaphragm dysfunction can be present in hypothyroidism, and sometimes the major manifestation of this disease may be respiratory failure due to respiratory muscle weakness.[19] Prolonged hyperglycemia, profound malnutrition, severe untreated renal failure, use of neuromuscular blocking agents, and sustained administration of high doses of corticosteroids may well contribute to reduced muscle strength in a subgroup of mechanically ventilated patients in the ICU.[19] The majority of diaphragm weakness in patients in the ICU, however, is not the consequence of easily treatable conditions. In many cases, diaphragm dysfunction is thought to occur primarily as a consequence of mechanical ventilation per se (ventilator-induced diaphragm dysfunction [VIDD]). There is also strong evidence that processes other than VIDD, including sepsis and other systemic infections are responsible for many cases of ICU-acquired diaphragm weakness. These two conditions will be discussed in more detail further on.

Ventilator-Induced Diaphragm Dysfunction

Ventilator-induced diaphragm dysfunction is the loss of diaphragm force-generating capacity that is specifically caused by the use of mechanical ventilation. The recent recognition that mechanical ventilation can induce diaphragm atrophy was convincingly made in animal studies. In one of these studies, Powers et al[20] reported that rats rapidly developed progressive diaphragm atrophy and loss of diaphragm force-generating capacity when mechanically ventilated using controlled mechanical ventilation. In this study, electromyography confirmed complete diaphragm inactivity, which was accomplished by using heavy levels of sedation. Subsequently, a series of patient studies provided evidence that ventilator-induced diaphragm atrophy also develops in patients undergoing mechanical ventilation. In one of these, Levine et al[21]reported that mechanically ventilated brain-dead organ donors rapidly experience severe diaphragm atrophy . In an earlier postmortem study, Knisely et al[22] found decreased diaphragmatic muscle mass and myofiber atrophy in infants and neonates who received long-term ventilatory assistance. A number of additional human studies, performed primarily in brain-dead organ donors, have since provided more evidence that diaphragm atrophy develops in patients who receive prolonged mechanical ventilation.[23]

To delineate the cellular mechanisms by which mechanical ventilation per se induces diaphragm atrophy and weakness, a number of elegant animal studies have shown that VIDD is associated with oxidative stress, activation of several proteolytic pathways (caspases, calpains, and the ubiquitin-proteasomal system), and mitochondrial dysfunction within the diaphragm, which induce loss of muscle size and strength. Additional studies suggest that ryanodine receptor dysfunction contributes to the pathology of VIDD and that activation of autophagy during VIDD provides a protective role. More recently, a number of studies have examined diaphragm tissues from patients undergoing prolonged mechanical ventilation and verified many of the findings observed previously in animal studies, largely confirming that

the same pathophysiological processes occur in patients with little or no respiratory drive undergoing mechanical ventilation.

Infection-Induced Diaphragm Dysfunction

The other potential contributor to the development of diaphragm weakness in mechanically ventilated patients is infection. Two clinical studies have suggested that infection is a major risk factor for the development of severe diaphragm weakness in critically ill mechanically ventilated patients.

Diagnostic Techniques

In general, there are two major forms of ultrasonographic assessment of the diaphragm: determination of diaphragm excursion and measurement of diaphragm thickening with the thickening fraction.

Doppler ultrasound detects the frequency shift of ultrasound signals reflected by moving objects.

Diaphragm excursion will be measured using a phased array probe, with the probe positioned in the subcostal margin in the mid-clavicular line, with the aim of imaging the posterior third of the diaphragm. The use of M-mode produces images that visualize the movement of the diaphragm over time and allows accurate measurement of diaphragmatic displacement over a respiratory cycle.

Diaphragm thickness will be measured in the zone of apposition, using a higher-frequency (>10 MHz) linear probe, to view the diaphragm as a three-layered structure, sandwiched between the two echogenic layers of the pleura and the peritoneum. It can be measured at expiration or end inspiration, and in both tidal and maximal breathing. Comparing expiratory with inspiratory thickness gives the thickening fraction, and is usually denoted as [(End Inspiratory Thickness−End Expiratory Thickness)/End Expiratory Thickness] and is an indicator of the work of breathing.

The diaphragm excursion was measured on the vertical axis of the M-mode tracing from the beginning to end of inspiration. At the same time, time for each tidal breath was recorded on the horizontal axis. The devised index, diaphragm excursion-time index (as measured by ultrasound) is a surrogate of the work performed by the diaphragm in

response to inspiratory loading during weaning from MV and is given by the product of diaphragmatic excursion and inspiratory time. It is hypothesized that when measured during an SBT, patients successfully extubated would have a lower RSBI, a longer time of inspiration, greater diaphragm excursion, and a higher E-T index.

Tissue Doppler imaging (TDI) is an echocardiographic technique that uses the same Doppler principles to measure the high-amplitude, low-velocity signal of cardiac tissue motion. TDI measurements are robust, easy to obtain, and offer valuable information in various cardiac pathologies. In recent years, ultrasonography has been used extensively to evaluate diaphragmatic motion characteristics, such as excursion and thickening, with derived measurements repeatedly being shown to carry prognostic implications in the outcome of weaning. However, TDI of diaphragmatic tissue motion has been studied so far very little in adults; moreover, little information exists regarding the waveform pattern of diaphragmatic motion velocity and its reference values in healthy subjects and in ICU patients with respiratory failure. E. Soilemezi et al[24] in their study have thrown some light regarding the TDI values in healthy individuals and those in critically ill patients with weaning success and failure. Atul Palkar et al[25] in their study on DETI have used it to predict extubation outcomes in patients on mechanical ventilation. So, in view of the very little data available on the new parameters of diaphragm assessment like DETI and TDI of the diaphragm, we have designed a prospective observational study first to evaluate the various diaphragm indices available for weaning prediction including the new ones and comparing them with the several other parameters which affect weaning from mechanical ventilation.

6.3 AIMS AND OBJECTIVES OF THE STUDY

Primary Objectives:

1. To assess role of diaphragm parameters on imaging during weaning from invasive mechanical ventilation.

2. To determine cut off of diaphragm excursion-time index and TDI values: for weaning success.

Secondary objectives:

1. To compare the ultrasononographic diaphragmatic values with lung mechanics and traditional weaning criteria.

HYPOTHESIS:

Diaphragm being the fundamental muscle for respiration, weaning success depends on the workload. Diaphragm excursion-time index is a surrogate of the diaphragm workload. Weaning success and weaning failure patients have strikingly different diaphragmatic patterns and TDI of the diaphragm is a predictor of diaphragmatic strength in the period following weaning.

7.0 MATERIALS AND METHODS

7.1 SOURCE OF DATA:

This is a Prospective observational study to be conducted at Intensive care units, Dayanand Medical College, Ludhiana

7.2 METHOD OF COLLECTION OF DATA

INCLUSION CRITERIA:

- All patients more than 18 years of age
- Patients who have been mechanically ventilated for more than 24hours and are now being planned for weaning after their cause for which they were on invasive mechanical ventilation has been resolved or is resolving will be included in the study.

EXCLUSION CRITERIA:

- Age <18 years
- Neuromuscular diseases
- Flail chest or multiple rib fractures
- Chest tubes in place
- Morbid obesity(BMI >40kg/m2)
- Malnutrition (BMI <18kg/m2)
- Spinal cord injuries
- Inability to obtain a clear TDI signal of the right hemi-diaphragm

STUDY PROTOCOL:

The study will be performed on 100 consecutive patients admitted to the ICU and are on invasive mechanical for any indication for >24 hours. The lung mechanics parameters, RSBI, DETI and Diaphragm excursion will be recorded.

Patients will be weaned off if they meet the following criteria: appropriate mental status and cooperation, adequate oxygenation (oxygen saturation as measured by pulse oximetry at least 92%, FIO2 40%) and cough reflex, cardiovascular stability without sssvasopressor or inotropic support, and normal metabolic status, RSBI <105, P/F ratio >150, PEEP requirement <10, relatively less secretions and improving chest imaging, MIP< -20 cm H2O, P0.1 <4 cm H2O, Vital capacity >10 ml/kg. Further weaning will be done by giving T-piece trial to these

patients with the concurrence of 2 Critical Care specialists. The sonographic examination in the ICU patients will be performed at the end of a 30-minute T-piece weaning trial or immediately before reconnection to the ventilator in the case of weaning failure occurring before. Reinstitution of mechanical ventilation will be initiated if signs of respiratory distress (diaphoresis or tachypnea), hypoxemia and/or hypercapnia, or deterioration of the cardiovascular status (hypertension and tachycardia) are observed. The sonographic examination will again be repeated at 24 hours. Weaning success will be considered if ventilatory support, including noninvasive ventilation, is not required for 48 hours after weaning.

All ultrasound measurements will be performed on the right hemi-diaphragm because of the limited acoustic window on the left. All the above mentioned diaphragmatic parameters are obtained with a phased array 2–4 MHz probe (Sonosite ultrasound machine). The probe is placed in the subcostal position between the mid-clavicular and anterior axillary lines, with the patients being examined while breathing spontaneously laying on a bed with the back elevated at 30 degrees. As these measurements are angle dependent, we will aim for the ultrasound beam to reach perpendicularly the middle or posterior third of the hemidiaphragm. The diaphragm thickness fraction is measured using the linear probe in the zone of apposition between the 8-10th ribs.

The sample volume for TDI to be initially selected at 5mm and occasionally adjusted to incorporate the whole range of diaphragmatic motion. The velocity scale to be used is 5 cm/sec to match the lower velocity of the moving diaphragm compared with that of the beating heart. four- six breaths per subject will be saved for subsequent quantitative analysis.

PARAMETRS TO BE MEASURED ON EACH PATIENT:

The following data will be recorded:

Name, age, sex, diagnosis, any co-morbidities, length of time under mechanical ventilation, reason for ICU admission, APACHE 2, SOFA, GCS, WBC Count, haemoglobin, albumin, pH, paCO2, P/F ratio, serum

lactate, NT- pro BNP, LVEF, BNP levels, respiratory rate, total time, diaphragmatic excursion and thickening fraction, CAM ICU score, MRC power grading of muscle, DETI and TDI. On each TDI waveform, the following parameters will be identified and measured:

1. Peak contraction velocity (PCV), defined as the maximal diaphragmatic velocity during contraction, and measured in cm/s;
2. Velocity–time integral (VTI), defined as the area under the TDI curve during inspiration, measured in (cm/s)
3. Peak relaxation velocity (PRV), defined as the maximal diaphragmatic velocity during relaxation, and measured in cm/s.

No of patients: The sample size is 100 patients.

OUTCOME:

Primary outcome: Improvement in prediction of weaning outcomes.

Secondary outcomes:

1.Early weaning

2. Improvement in no. of ventilator free days of the patient.

STATISTICAL ANALYSIS:

Recorded variables, including diaphragmatic excursion, thickness fraction, DETI and TDI will be compared to clinical parameters and lung mechanics and other causes of weaning failure. They will be presented as means + SD or medians, according to normality of distribution of values, as appropriate. Outcome will be assessed as dichotomous categorical variable (weaning success vs. weaning failure). Group comparisons will be performed with chi-square, Student's t test, or Mann Whitney U test. Our primary hypothesis (that different diaphragm ultrasound variables differ between weaning success and weaning failure patients) will be tested with statistical analysis of comparison of two independent groups. Sample size will be calculated in advance. P values will be considered statistically significant at the 0.05 level.

Reliability analysis will include assessment of intra- and inter observer variability with two-way mixed effects for absolute agreement between measurements for each TDI variable separately. Interclass Correlation Coefficient (ICC) and its relative 95% confidence intervals will be estimated, and ICC values .0.8 will be considered very strong.

Reproducibility was also assessed by calculating the mean difference between all pairs of measurements, according to Bland and Altman plotting, reflect the range that has 95% statistical validity. In addition, the coefficient of variance will calculated to assess intra-subject variability.

7.3 DOES THE STUDY REQUIRE ANY INVESTIGATIONS OR INTERVENTIONS TO BE CONDUCTED ON PATIENTS OR OTHER HUMANS OR ANIMALS? IF SO, PLEASE DESCRIBE BRIEFLY.

Use of ultrasonography for diaphragm assessment, ABG for blood gases and lactates and echocardiography for LVEF

7.4 HAS ETHICAL CLEARENCE BEEN OBTAINED FROM YOUR INSTITUTION IN CASE OF 7.3?

Attached Herewith

8.0 LIST OF REFERENCES

1. Béduneau G, Pham T, Schortgen F. Epidemiology of weaning outcome according to a new definition. The WIND study. Am J Respir Crit Care Med. 2017;195:772–83.
2. Epstein SK, Ciubotaru RL, Wong JB. Effect of failed extubation on the outcome of mechanical ventilation. Chest. 1997;112:186–92.
3. Thille AW, Harrois A, Schortgen F. Outcomes of extubation failure in medical intensive care unit patients. Crit Care Med. 2011;39:2612–8.
4. Gottesman E, McCool FD. Ultrasound evaluation of the paralyzed diaphragm. Am J Respir Crit Care Med. 1997;155:1570–4
5. Petrof BJ, Jaber S, Matecki S. Ventilator-induced diaphragmatic dysfunction. Curr Opin Crit Care. 2010;16:19–25
6. Kim WY, Suh HJ, Hong SB. Diaphragm dysfunction assessed by ultrasonography: influence on weaning from mechanical ventilation. Crit Care Med. 2011;39:2627–30.
7. Diehl JL, Lofaso F, Deleuze P, Similowski T, Lemaire F, Brochard L. Clinically relevant diaphragmatic dysfunction after cardiac operations. J Thorac Cardiovasc Surg. 1994;107:487–98
8. Tobin MJ, Laghi F, Brochard L. Role of the respiratory muscles in acute respiratory failure of COPD: lessons from weaning failure. J Appl Physiol. 2009;107:962–70
9. Laghi F, Cattapan SE, Jubran A. Is weaning failure caused by low-frequency fatigue of the diaphragm? Am J Respir Crit Care Med. 2003;167:120–7.
10. Matamis D, Soilemezi E, Tsagourias M, Akoumianaki E, Dimassi S, Boroli F, et al. Sonographic evaluation of the diaphragm in critically ill patients: technique and clinical applications. Intensive Care Med 2013;39:801–10
11. McCool FD, Tzelepis GE. Dysfunction of the diaphragm. N Engl J Med. 2012;366:932–42.
12. Supinski GS, Callahan LA. Diaphragm weakness in mechanically ventilated critically ill patients. Crit Care. 2013;17:R120.

13. Esteban A, Ferguson ND, Meade MO. Evolution of mechanical ventilation in response to clinical research. Am J Respir Crit Care Med 2008; 177:170–7.
14. Esteban A, Alia I, Gordo F. Extubation outcome after spontaneous breathing trials with T-tube or pressure support ventilation. The Spanish Lung Failure Collaborative Group. Am J Respir Crit Care Med 1997; 156:459–65.
15. Vallverdu I, Calaf N, Subirana M. Clinical characteristics, respiratory functional parameters, and outcome of a two-hour T-piece trial in patients weaning from mechanical ventilation. Am J Respir Crit Care Med 1998; 158:1855-62.
16. Frutos-Vivar F, Esteban A, Apezteguia C, et al. Outcome of reintubated patients after scheduled extubation. J Crit Care 2011; 26:502–509.
17. Fan E, Cheek F, Chlan L. An official American Thoracic Society Clinical Practice guideline: the diagnosis of intensive care unit-acquired weakness in adults. Am J Respir Crit Care Med. 2014;190:1437-46.
18. Tennilä A, Salmi T, Pettilä V. Early signs of critical illness polyneuropathy in ICU patients with systemic inflammatory response syndrome or sepsis. Intensive Care Med. 2000;26:1360–136.
19. Powers SK, Shanely RA, Coombes JS. Mechanical ventilation results in progressive contractile dysfunction in the diaphragm. J Appl Physiol. 2002;92:1851–8.
20. Levine S, Nguyen T, Taylor N. Rapid disuse atrophy of diaphragm fibers in mechanically ventilated humans. N Engl J Med. 2008;358:1327-35.
21. Knisely AS, Leal SM, Singer DB. Abnormalities of diaphragmatic muscle in neonates with ventilated lungs. J Pediatr. 1988;113:1074-7.
22. Soilemezi E, Savvidou S, Sotiriou P, Smyrniotis D, Tsagourias M, Matamis D. Tissue Doppler imaging of the diaphragm in healthy

subjects and critically ill patients. American Journal of Respiratory and Critical Care Medicine. 2020;202:1005-12.

23. Palkar A, Narasimhan M, Greenberg H, Singh K, Koenig S, Mayo P, et al. Diaphragm excursion-time index: a new parameter using ultrasonography to predict extubation outcome. Chest. 2018;153:1213-20.
24. Esteban A, Ferguson ND, Meade MO. Evolution of mechanical ventilation in response to clinical research. Am J Respir Crit Care Med. 2008;177:170-7.
25. Esteban A, Alia I, Gordo F. Extubation outcome after spontaneous breathing trials with T-tube or pressure support ventilation. The Spanish Lung Failure Collaborative Group. Am J Respir Crit Care Med. 1997;156:459-65.

PROFORMA

Sr. No

NAME AGE SEX

BMI-

LENGTH OF TIME UNDER MECHANICAL VENTILATION (in days)

REASON FOR ICU ADMISSION

Any comorbidities: YES NO

1.DM

2.HTN

3.CLD

4.CKD

5.Thyroid dysfunction

6.CAD

7.COPD

8.Any hematological disease

APACHE 2

SOFA

GCS

MRC grading of muscle power

Lung Mechanics-

RSBI

P 0.1 sec-

Negative inspiratory Force

Signature of Candidate

Signature of Supervisor

Others-

WBC Count

Haemoglobin

Albumin

LVEF

BNP levels

Calcium

Potassium

Phosphorus

CAM -ICU

ABG on mechanical ventilation(MV)

ABG after SBT(after 30 minutes)

ABG after SBT(after 24 hours)

I. Diaphragm parameters on mechanical ventilation

a. Diaphragmatic excursion

Reading 1	Reading 2	Reading 3	Mean

b. Diaphragmatic excursion time index (DETI)

Reading 1	Reading 2	Reading 3	Mean

Signature of Candidate

Signature of Supervisor

II. Diaphragm parameters during SBT after 30 minutes of weaning trial

a. Diaphragmatic excursion

Reading 1	Reading 2	Reading 3	Mean

b. Diaphragmatic excursion time index(DETI)

Reading 1	Reading 2	Reading 3	Mean

c. Diaphragmatic thickening fraction

	Reading 1	Reading 2	Reading 3	Mean
Inspration				
Expiration				

(End Inspiratory Thickness−End Expiratory Thickness)/End Expiratory Thickness]=DTF

d. TDI Measurements

PCV (Peak contraction velocity)

Reading 1	Reading 2	Reading 3	Mean

PRV (Peak relaxation velocity)

Reading 1	Reading 2	Reading 3	Mean

VTI (Velocity time integral)

Reading 1	Reading 2	Reading 3	Mean

Signature of Candidate

Signature of Supervisor

III. Diaphragm parameters during SBT after 24 hours of weaning

a. Diaphragmatic excursion

Reading 1	Reading 2	Reading 3	Mean

b. Diaphragmatic excursion time index(DETI)

Reading 1	Reading 2	Reading 3	Mean

c. Diaphragmatic thickening fraction

	Reading 1	Reading 2	Reading 3	Mean
Inspiration				
Expiration				

(End Inspiratory Thickness−End Expiratory Thickness)/End Expiratory Thickness]=DTF

d. TDI Measurements

PCV (Peak contraction velocity)

Reading 1	Reading 2	Reading 3	Mean

PRV(Peak relaxation velocity)

Reading 1	Reading 2	Reading 3	Mean

VTI (Velocity time integral)

Reading 1	Reading 2	Reading 3	Mean

Signature of Candidate

Signature of Supervisor

INFORMED PATIENT CONSENT

Date: _____

I.....D/o, W/o, S/o.....
.....am willing to participate in the study **"EVALUATION OF DIAPHRAGM ULTRASONOGRAPHY IN PREDICTING WEANING OUTCOMES FROM MECHANICAL VENTILATION"** The procedure with its complications has been explained to me in local vernacular language. I have fully understood that no special tests and extra expenditure in any form, merely for the purpose of thesis is being carried out. I am free to opt out the study any time without assigning any reason.

.....	.....
Signature of the Witness	Signature of the patient / Legal representative
Name:	Name:

Signature of Candidate **Signature of Supervisor**

मरीज अनुमति फार्म

तिथि _____

मैं _____ पत्नी/पुत्र/पुत्री _____

निवासी _____

इस शोधकार्य **"EVALUATION OF DIAPHRAGM ULTRASONOGRAPHY IN PREDICTING WEANING OUTCOMES FROM MECHANICAL VENTILATION"** में भाग लेने के लिए सहमत हूँ। मैं इस शोधकार्य में भाग लेने के लिए अपनी स्वेच्छा से तैयार हूँ। मैं पुष्टि करता/करती हूँ की यह स्वीकृति देने के लिए मुझे कोई आर्थिक प्रलोभन नहीं दिया गया और न ही दबाव डाला गया है। मुझे इस शोधकार्य का उद्देश्य स्पष्ट कर दिया गया है और मुझे यह विश्वास है की यह विज्ञान और मानवता के लाभ के लिए है। मुझे इस शोधकार्य में होने वाले जोखिम के बारे में समझा दिया गया है और मेरी समझ में यह ज़ोखिम बहुत मामुली है।

मैं इस शोधकार्य में भाग लेने के सम्बन्ध में किसी भी समय अपनी अस्वीकृति व्यक्त कर सकता/सकती हूँ और मेरे अस्वीकृति व्यक्त करने का मेरे इलाज पर कोई प्रभाव नहीं पड़ेगा।

_____ _____

गवाह के हस्ताक्षर रोगी/ प्रतिनिधि के हस्ताक्षर /अंगूठे का निशान

नाम: नाम:

_____

अन्वेषक के हस्ताक्षर

_____

विद्यार्थी के हस्ताक्षर

ਮਰੀਜ਼ ਰਜ਼ਾਮੰਦੀ ਫਾਰਮ

ਮਿਤੀ_____

ਮੈ_____ਪਤਨੀ/ਪੁੱਤਰ/ਪੁੱਤਰੀ_____

ਵਾਸੀ _____

"EVALUATION OF DIAPHRAGM ULTRASONOGRAPHY IN PREDICTING WEANING OUTCOMES FROM MECHANICAL VENTILATION" ਤੇ ਚਲ ਰਹੀ ਖੋਜ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਰਜ਼ਾਮੰਦ ਹਾਂ। ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਮੈ ਆਪਣੀ ਮਰਜ਼ੀ ਨਾਲ ਤਿਆਰ ਹਾਂ। ਮੈ ਇਹ ਦਸਣਾ ਚਾਹੁੰਦਾ ਹਾਂ/ ਚਾਹੁੰਦੀ ਹਾਂ ਕੇ ਇਹ ਰਜ਼ਾਮੰਦੀ ਦੇਣ ਵਾਸਤੇ ਮੈਨੂ ਕਿਸੇ ਵੀ ਤਰਾਂ ਦਾ ਲੋਭ-ਲਾਲਚ ਨਹੀ ਦਿੱਤਾ ਗਿਆ ਅਤੇ ਨਾ ਹੀ ਕੋਈ ਦਬਾ ਪਾਇਆ ਗਿਆ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਦਾ ਮਨੋਰਥ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ ਅਤੇ ਮੈਨੂ ਇਹ ਭਰੋਸਾ ਦਵਾਇਆ ਗਿਆ ਹੈ ਕੇ ਇਹ ਖੋਜ ਵਿਗਿਆਨ ਅਤੇ ਮਾਨਵਤਾ ਦੀ ਭਲਾਈ ਲਈ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਵਿਚ ਹੋਣ ਵਾਲੇ ਖਤਰੇ ਬਾਰੇ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ ਅਤੇ ਮੈਨੂ ਇਹ ਯਕੀਨ ਹੈ ਕੇ ਇਹ ਖਤਰਾ ਬਹੁਤ ਮਾਮੂਲੀ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਦਾ ਢੰਗ – ਤਰੀਕਾ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ।

ਮੈ ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਬਾਰੇ ਆਪਣੀ ਰਜ਼ਾਮੰਦੀ ਕਿਸੇ ਵੀ ਸਮੇ ਵਾਪਸ ਲੈ ਸਕਦਾ ਹਾਂ/ ਸਕਦੀ ਹਾਂ ਅਤੇ ਮੇਰੀ ਰਜ਼ਾਮੰਦੀ ਵਾਪਸ ਲੈਣ ਦਾ ਮੇਰੇ ਇਲਾਜ ਤੇ ਕੋਈ ਅਸਰ ਨਹੀ ਹੋਵੇਗਾ।

_____ _____

ਗਵਾਹ ਦੇ ਹਸਤਾਖਰ ਮਰੀਜ਼ / ਪ੍ਰਤੀਨਿਧੀ ਦੇ ਹਸਤਾਖਰ

ਮਿਤੀ_____ ਮਿਤੀ_____

ਪਤਾ _____ ਪਤਾ _____

_____

ਨਿਰੀਖਕ ਦੇ ਹਸਤਾਖਰ

_____

ਸਿਖਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ